ILLINOIS BIOLOGICAL MONOGRAPHS

VOLUME XII

PUBLISHED BY THE UNIVERSITY OF ILLINOIS

URBANA, ILLINOIS

ILLINOIS BIOLOGICAL MONOGRAPHS

Vol. XII No. 4

PUBLISHED BY THE UNIVERSITY OF ILLINOIS
UNDER THE AUSPICES OF THE GRADUATE SCHOOL
URBANA, ILLINOIS

DISTRIBUTED
JUNE 20, 1934

1000—6-34—4855

UNIVERSITY
OF ILLINOIS
:: PRESS ::

A STUDY OF FRESH-WATER PLANKTON COMMUNITIES

WITH NINE FIGURES

BY

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CONTRIBUTION FROM THE ZOOLOGICAL LABORATORY OF THE
UNIVERSITY OF ILLINOIS
No. 448

CONTENTS

ACKNOWLEDGMENTS

The writer wishes to thank Professor V. E. Shelford, under whose direction this study was made, for his advice and encouragement. The writer is especially indebted also to Professor S. A. Forbes, late chief of the Illinois State Natural History Survey, for the use of the survey collections and data from the Mississippi, Illinois, and Ohio rivers and from the glacial lakes of northern Illinois. Mr. Arthur Hjortland, of the University of Illinois, kindly made collections for the writer from lakes in the vicinity of Ely, Minnesota, and from Lake Superior. Professor H. J. Van Cleave and many other members of the faculty and graduate students of the Zoology Department of the University of Illinois have made and contributed collections from distant points, many of which, although not directly referred to in this paper, have helped the writer in reaching his conclusions. Professor Van Cleave and Professor L. A. Adams, both of the Zoology Department, and Mr. H. Carl Oesterling, then editor of the Illinois State Natural History Survey, read and criticised preliminary drafts. To all these the writer wishes to express his appreciation.

INTRODUCTION

Various ecologists have frequently demonstrated that both plants and animals exist on land in well-defined communities, but have given comparatively little attention to the existence and character of similar communities in water. Land communities show definite development and behavior. Certain species known as "predominants" (Smith, 1928), or "prevalents," are conspicuous in land communities because of their size or because of their abundance due to a favorable response to the conditions and they serve as an index to the community. Some of them have approximately the same abundance throughout the year, while others show seasonal fluctations in abundance and indicate the presence of seasonal societies or "socies" (Clements, 1916). Some predominants, known as "euryoecious" species, have such widespread distribution as to mark the boundaries of the formation, which is the community of greatest rank. Others of limited distribution are termed "stenoecious" and indicate the boundaries of communities of associational rank.

Land communities develop and reach maturity by a long series of successional stages. If comparable fresh-water communities exist, they may be expected to reach maturity through a series of developmental stages. Communities of various ranks comparable to similar aggregations on land should be definitely ascertainable in fresh water. It should be possible to show a series of developmental communities ultimately reaching a permanent stable condition equivalent to that of a terrestrial climax community, as outlined by plant ecologists (Clements, 1916).

Most ecologists have assumed that permanent fresh-water communities do not exist and that aquatic communities are but early developmental stages of terrestrial ones. The writer believes that permanent fresh-water communities exist, reach maturity, and show aspects comparable to terrestrial communities (Shelford and Eddy, 1929).

Aquatic communities should demonstrate their stability and permanence by maintaining a composition in which no further succession takes place. Their rank and status should be determined by the presence of predominant or dominant organisms. It is part of the purpose of this paper, by studying plankton as an index to the pelagic portion of fresh-water communities, to determine the existence, rank, behavior, and status of the plankton element.

"Plankton" has been variously defined by many authorities. Hensen (1887) originally defined the term as denoting all that floats in water, "Alles was in Wasser treibt." Kolkwitz (1912) defined the term as the natural community of those organisms that are normally living in water

and are passively carried along by currents. Rylov (1922) in discussing the forms which come under the term plankton, uses the terms "obligoplankton," referring to true planktonts only, and "facultative planktonts," referring to those forms found in both limnetic and littoral regions, and also states that "pelagic organisms" are not the same as "planktonts," for planktonts may be both pelagic and littoral. Plankton investigators usually include under the term all forms found in open waters regardless of origin; consequently, they often include many bottom and shore forms. As the term is restricted to minute forms and does not include the larger organisms such as fishes, the writer regards the term as applied to an aggregation of organisms constituting all microscopic forms found in open waters. Properly speaking, although seldom recognized as such, bacteria living in open waters should be included under the term "plankton." A common definition includes those forms with little or no resistance to currents, living a free-floating or suspended existence in open or pelagic waters.

Kolkwitz and Marsson (1902, 1908, 1909) have attempted to classify plankton from the standpoint of pollution, using plankton organisms as indicators of degrees of pollution. Wesenberg-Lund (1908), Bachmann (1921), Smith (1920), Naumann (1927), and Krieger (1927) all have attempted to classify plankton in terms of plankton constituents and relations to the habitats. Griffith (1923) has classified plankton algae in terms of the ecological features prevalent in the habitat. From such attempts have arisen such terms as "rheoplankton" (river), "benthoplankton" (shallow pond), "limnoplankton" (deep pond), "heleoplankton" (pond), and many others, all describing the plankton on the basis of habitats. The writer realizes that all these types of plankton are distinct and can be distinguished from each other by their specific composition but believes that they should be classified on the basis of the abundant or conspicuous organisms which act as indicators because of their favorable response to environmental conditions. A true ecological classification of plankton should recognize plankton as a part of a living community which is comparable to an organic unit passing through the stages of youth and maturity.

The animals of any considerable body of water group themselves into two natural communities, the bottom and the pelagic communities, which may be termed societies or socies as they correspond to the terrestrial stratal societies or socies of Clements (1916). The true community dominants, namely, fishes, do not respect the difference between bottom and open waters. Most fishes are, properly speaking, bottom organisms but their constant forays into open waters place them as important factors in the pelagic community. These socies offer an interrelationship that is unique and entirely different from that of the cor-

responding terrestrial groups. Terrestrial societies all rest on solid substrata, and we know of no group of terrestrial animals which spend their entire existence suspended in the surrounding medium. The organisms of pelagic societies are always suspended in the water. Type of bottom cannot influence the reactions of organisms of the pelagic societies as it does those of the bottom society, which are usually in close contact with the bottom. Furthermore, the pelagic society is constantly shifting with currents or waves, while that of the bottom remains fixed. The development of the pelagic society is not as closely related to, and dependent on, the development of the bottom society, as is the development of the various terrestrial stratal societies to each other. In newly formed bodies of water, as will be discussed later, the pelagic society develops much faster than the bottom society.

The organisms of the plankton constitute an important element in the pelagic community. Over 500 species of organisms have been reported from the plankton of the waters of the State of Illinois. Practically the only other organisms existing in this fresh-water community are the pelagic fishes, which are usually dominants; and in both numbers and species, the plankton organisms greatly out-number these. Truly pelagic or nektonic fishes are rare in fresh waters and are limited to such forms as the cisco and other coregonid fishes which occur only in very deep lakes.

The plankton serves as a convenient index to pelagic communities. Quantitative collections are easily obtained. The great abundance and number of species give a greater range of data than fishes afford. The organisms serve as a good index to general conditions because of their inability to resist currents and to move into more favorable areas; consequently, their abundance may be considered as evidence of favorable reactions to the conditions of the habitat.

In land communities certain species are abundant and therefore conspicuous because of their favorable reactions to environmental conditions and are known as "predominants" or "prevalents." Others, known as "dominants," usually fishes in fresh water, exercise some control over the community and are responsible, in part at least, for its existence. Cahn (1929) found indications that carp introduced into a lake could destroy the vegetation and change the character of the bottom to such an extent as to alter the fish population. Organisms forming important elements in food chains are known as "influents." "Characteristic" organisms are those forms which may serve as indicators of conditions. They are not necessarily abundant; indeed, they are often rather scarce, their mere presence or absence being more significant than their abundance. These terms should be applicable also to fresh-water organisms insofar as communities in water are comparable to those on

land. In this paper we are chiefly concerned with the characteristic and abundant or predominant organisms, which include both seasonals and perennials, as our knowledge and data on interrelations between aquatic organisms are insufficient to determine the other types definitely. Accordingly, all abundant or characteristic species are considered either as perennial predominants ("perennials") or as seasonal predominants ("seasonals") until more is understood about their relations to other members of the community. It is probable that many plankton organisms act as influents by serving as vital elements in the foods of other forms and possibly even as dominants in controlling the community by this action and by clearing up waste and inorganic materials, thus preparing conditions whereby other forms can exist.

Another group of organisms found in the plankton may be termed "incidentals." These forms often constitute more than half of the species but are sporadic and seldom abundant. Such forms generally occur once or twice a year and frequently originate from foreign sources. Therefore, as they are apparently not significant or important to the community, their presence has been generally disregarded in this study and only considered when describing the entire plankton population.

Communities are determined by their organic constitution, in which one or more species stand out and serve as indicators, and by the physiographic state of their habitat. The first analysis of a community should be made from a physiographic study. This is best applied to both permanent and developmental communities. The conception held by most ecologists, that aquatic communities are developmental stages of land communities, is not necessarily true in all cases. Streams are permanent so long as the existing climate endures, and this is the same condition under which land communities reach and maintain a permanent or climax stage. Only the abandoned areas of streams become developmental stages of land communities. Apparently streams contain the only permanent fresh-water communities. Streams show a definite physiographic development, from the small intermittent stream, with its rapid fall, to the large permanent stream approaching a base level and having a uniform current (Shelford, 1913). Their characteristic fluctuations of current and level make it difficult to study their communities.

All lakes are, at least in part, developmental stages of land communities. Physiographically, the ultimate fate of even the deepest lake is to become a swamp proceeding toward a terrestrial climax. Many lakes are enlarged stream channels, forming large and deep bodies of waters. These are best considered as abandoned parts, or natural duplications of abandoned parts, inasmuch as in their later stages, when they proceed toward land, they contain communities similar to stream portions actually abandoned.

AREAS STUDIED

In order to secure the data necessary for the study of plankton as an element of aquatic communities, it was essential to select ponds, lakes, and streams representing all stages of physiographic development. This paper is based on data obtained from more than two thousand collections studied from this viewpoint. Advantage was taken of several dams and canals to furnish quasi-experimental evidence on development and maturity of plankton communities. The most extensive data were obtained from the Sangamon River, a tributary of the Illinois River, between Mahomet and Decatur, Illinois. Collections on this stream were made semi-monthly or weekly at Decatur from 1923 to 1929, at Monticello from 1927 to 1929, and at Mahomet from 1928 to 1929. Collections also were made at stations ten to fifteen miles apart over the entire Rock River system and the Illinois-Mississippi Canal under the direction of the Illinois State Natural History Survey during the summers of 1925, 1926, and 1927. Ponds at Decatur and Urbana were studied semi-monthly from 1926 to 1929. Temporary ponds in the vicinity of Urbana and Seymour, Illinois, were studied weekly during their wet periods in 1926 and 1928. Many occasional collections have been made and studied from various parts of the United States whenever opportunity was afforded to the writer. In addition, extensive collateral data have been obtained from collections made by other workers as follows: by Dr. C. A. Kofoid from the Illinois, Mississippi, and Ohio rivers; by Mr. R. E. Richardson from the Illinois, Mississippi, Ohio, and Fox rivers and from the glacial lakes of northern Illinois; by Dr. S. A. Forbes from lakes of Yellowstone Park and Wisconsin; by Dr. H. J. Van Cleave from lakes of New Mexico, Arizona, and California; by Prof. Frank Smith from lakes in Colorado and Michigan; by Dr. R. D. Bird from lakes in San Juan County, Washington; by Mr. A. L. Hjortland from lakes in Minnesota; by Miss Beth Hefelbauer from lakes in New York; and by Mr. E. E. Wehr from lakes in Montana.

METHODS

The usual methods of collecting by silk net, decantation, filter paper, and centrifuge were employed. Each set of collections consisted of a silk-net collection with an additional collection by one of the other three methods for the purpose of obtaining data on the nannoplankton. At least two samples of each collection were counted in a Sedgwick-Rafter slide, an entire cubic centimeter being counted instead of the usual ten random counts on a single sample. The 200 fields of the microscope on

the slide were divided into ten groups, and the counts of all these groups were made separately and then averaged. From the averages thus obtained on the two samples, the numbers of organisms were finally computed per cubic meter, which was the standard unit volume. This method gave a more representative list of species as well as a better average than is usually secured by the common method of basing computation on a single count of 0.1 cc. It is well known that the silk net is very inefficient and allows many of the smaller organisms to escape through the fine meshes. However, as larger quantities of water could be used (100 liters), it gave better qualitative data than could be obtained by any of the other methods. The quantitative data from the silk net, after repeated tests, showed reasonable accuracy for the larger forms such as the Entomostraca. All the collections referred to in the tables of data in this paper were made with a net of No. 25 bolting silk unless otherwise indicated.

The decantation method proved to be a quite accurate and very convenient method for collecting nannoplankton. A known volume (1000 cc.) of the water was treated with 2 cc. of formalin and allowed to settle for two weeks. The water was carefully siphoned off until only about 20 cc. remained, which was saved with the residue for counting. When floating organisms were present, care was taken not to siphon off any of the surface water. Many of the nannoplankton collections from Lake Decatur and the Sangamon River were of this type. Most of the plankton collections from other waters studied were filter-paper or centrifuge collections.

As plankton organisms are known to vary in vertical distribution, collections were made at several levels in waters where there was little current. By means of either a pump or water bottle, collections were made from two or three levels depending on the depth. Averaging the collections from the different levels served to equalize the variations in vertical distribution. Whenever a current was present and repeated tests had showed no vertical variation, the collections were made either by dipping with a bucket or by pumping a known volume of water from two feet below the surface.

In an effort to find correlations with the distribution of the organisms, the physical conditions of the water were determined as far as possible for each collection taken. At most of the stations tests for dissolved oxygen were made in the various seasons of 1928-29, by the Winkler method (Winkler, 1888) as described by Birge and Juday (1911). The temperature and pH of the water were determined at each collection. Also the level of the water, the turbidity, and the current were noted each time.

Where weekly or semi-monthly collections were made, the data were averaged and tabulated on the monthly basis for convenience. The author is well aware of the many fluctuations in abundance occurring within short periods of even a week, but the long tables necessary to include these detailed data are undesirable because of their additional bulk. Such observations are desirable for a detailed study of plankton, but in a general study monthly averages serve very well.

For each station where series of seasonal collections were made, the organisms have been tabulated in order of abundance or importance and according to their seasonal arrangement, without any regard to their systematic order. This is essential in an ecological paper where distribution is of more importance than systematic relations. As in terrestrial communities, the abundance of organisms is not always the index to their importance. Some very small organisms are very abundant, running into billions per cubic meter, while others much larger are equally important though running only a few hundred per cubic meter.

CONSTITUTION OF THE PLANKTON IN STREAMS

In an ecologically "mature" community there is no change in most of the predominant species from year to year. Such communities should be distinguished from "developmental" communities by their relative stability and by the absence of invaders which would establish different sets of conditions. Communities may be distinguished from others of different status by the presence of abundant or predominant organisms serving as indicators of given sets of conditions.

Stable Streams

Streams for the study of mature communities should be selected first on a physiographical basis. Alterations in the channel, changing the physical or chemical conditions of the water, by an increase in turbidity, by the introduction of water of recent origin, or by an increase in rate of flow, may retard the rate of development or change the ecological age of the water at any given point. The tendency is to wear away the stream bed, creating a more uniform channel. No stream perhaps ever completely reaches the limit of old age, as the upper course is usually in such a physiographic condition as to produce a volume of silt which more or less affects the lower portion. Most of the streams of the United States are in the process of aging, but hardly any two are in the same physiographical stage. Therefore, since the physiographical stages show considerable variation, it is necessary to select those suitable for

the study of the ecological conditions of maturity. The current should be relatively slow and uniform. The Illinois River approaches these conditions very closely. The Mississippi and the Ohio are not as mature as the Illinois. Purdy (1923) states that the Ohio is geologically young, not having reached a base level and being consequently subject to considerable channel erosion. The Mississippi channel is subject to erosion and receives much silt from tributaries; consequently the water is very turbid. Summer collections from Rock Island to Cairo, made by C. A. Kofoid in 1902 and R. E. Richardson in 1908 for the Illinois Natural History Survey, have been examined by the writer and show an abundance of silt and a scanty plankton (Table 1). The same seems to be true of collections by the same investigators from the Ohio between Paducah and Cairo. Galtsoff (1924) in his investigations on the upper Mississippi found the plankton more abundant upstream. He reports a rather general distribution of the following plankton organisms in the section of the river between Hastings, Minnesota, and Alexandria, Missouri: algae, *Microcystis aeruginosa, Aphanizomenon flos-aquae, Scenedesmus quadricauda, Pediastrum duplex;* protozoans, *Eudorina elegans, Codonella cratera;* and rotifers, *Filinia longiseta, Polyarthra trigla, Brachionus calyciflorus, Brachionus capsuliflorus* (varieties), and *Keratella cochlearis.* The writer found the plankton to be rather rare both in species and in abundance in the collections of Kofoid and Richardson from the Ohio and the Mississippi. Purdy (1923) gives no definite information as to the specific content of the plankton of the lower Ohio but states that in the Paducah district the plankton is scarce.

The collections made by Richardson from the Ohio and the Mississippi were made continuously by pumping a stream of water through a plankton net suspended in a barrel on deck as the boat traveled down the Mississippi and up the Ohio. In the regions listed in Table 1, little difference existed between the collections within a given region, so that an average of the collections gave a typical and representative list of the plankton for that area. *Difflugia lobostoma* was the most abundant form in the Ohio. The other but less abundant forms were the usual river planktonts as follows: *Pediastrum duplex, Keratella cochlearis, Polyarthra trigla, Cyclops viridis, Filinia longiseta,* and *Brachionus angularis.*

The Mississippi from Rock Island to Cairo may be divided into two sections as distinguished by plankton production. The upper section, from Rock Island to the mouth of the Missouri, carried a plankton much richer both in species and in numbers than the lower section, between the mouth of the Missouri and the mouth of the Ohio. This is at least in part due to the increase in silt from the waters of the Missouri—an

increase which was distinctly noticeable in the collections. The plankton of the lower section was very similar to that of the Ohio, containing the same predominants, or prevalents, with the addition of *Daphnia longispina, Cyclops bicuspidatus, Pedalia mira,* and *Brachionus budapestinensis.* The upper section not only contained the same species in greater abundance but, as may be noted in Table 1, contained many other species which are common river predominants.

The Illinois River approaches the physiographic conditions of a mature stream more closely than the Mississippi or the Ohio. According to Kofoid (1903), the Illinois River occupies an ancient and well-worn preglacial channel which causes the stream to have little fall and a slow current. The erosion and turbidity seem to be less than in the Mississippi. Kofoid reports a fall of only 0.13 feet per mile in the Illinois River from Utica, Illinois, to the mouth; while Galtsoff reports a fall of 0.44 feet per mile in the Mississippi from St. Paul to Alexandria. The writer has examined many collections from the Illinois between Utica and the mouth which agree in species and relative abundance with the extensive data collected by Kofoid. In addition to the recent collections made by Mr. R. E. Richardson and the writer, the collections and unpublished data of Kofoid for the years 1896 and 1897 have been recounted and checked by the writer, and tabulated monthly (Table 2). These data, together with those for 1898 published by Kofoid (1908), represent the seasonal distribution of the plankton for perhaps the most mature stream yet studied in North America. Certain species such as *Lysigonium granulatum, Polyarthra trigla, Keratella cochlearis, Difflugia lobostoma,* and *Codonella cratera* are shown to be definitely perennial, existing through all seasons of the years studied. Others are seasonals, appearing regularly at definite periods as discussed later. In general, the plankton is very abundant below the points of pollution. The predominants mentioned as occurring in the Ohio occurred in the Illinois as either perennials or seasonals.

An extensive survey of the summer plankton of the Rock River from near the source to the mouth showed an abundance of the same predominants as found in the Illinois. A series of dams throughout its length creates many pools which serve to stabilize the current. Weekly collections were made at 10-15 mile intervals from the Wisconsin line to the mouth of the river. The specific content of the plankton was found to be the same at different points although there was some variation in abundance due to local conditions. The station at Sterling was selected as being very typical of the Rock River, and the predominant, or prevalent, organisms for the months of June, July, and August, 1926, have been averaged (Table 1). *Trachelomonas volvocina, Codonella*

cratera, Polyarthra trigla, Pediastrum duplex, and many other forms appearing as perennials and seasonals in the Illinois River, appeared in the Rock River abundantly.

Collections from the Fox River at Algonquin, Illinois, made by Mr. R. E. Richardson in the summer of 1916, were counted, averaged, and are tabulated in Table 1. The plankton of the Fox River was rather abundant in both numbers and species and contained most of the predominants found in the Illinois in summer, in nearly the same relative abundance.

A tow made from the Wabash River at Mt. Carmel, Illinois, in the spring of 1927 when the river was at flood stage, contained many of the predominants which occurred at the same season in the Illinois. In all the large streams examined which seem to approach stability, the same plankton predominants occurred, though with some irregularity.

The most abundant or conspicuous of the predominant, or prevalent, species of the plankton of a stable, or permanent, river community in the region studied are as follows:

Algae

Microcystis aeruginosa
Lysigonium granulatum
Scenedesmus quadricauda
Asterionella gracillima
Pediastrum duplex
Closterium acerosum

Protozoa

Trachelomonas volvocina
Difflugia globulosa
Difflugia lobostoma
Codonella cratera
Synura uvella
Stentor coeruleus
Phacus longicauda
Eudorina elegans
Euglena acus
Euglena viridis
Euglena oxyuris
Tintinnidium fluviatilis
Ceratium hirundinella

Cladocera

Chydorus sphaericus
Bosmina longirostris
Daphnia longispina
Moina micrura
Leptodora kindtii

Rotatoria

Polyarthra trigla
Brachionus calyciflorus
Brachionus capsuliflorus
Brachionus angularis
Brachionus budapestinensis
Brachionus havanaensis[1]
Keratella cochlearis
Keratella quadrata
Notholca striata
Filinia longiseta
Conochiloides natans
Pedalia mira
Asplanchna brightwellii
Synchaeta pectinata
Synchaeta stylata

Copepoda

Cyclops viridis
Cyclops bicuspidatus
Diaptomus pallidus
Diaptomus siciloides

These species occurred either as seasonals or as perennials in the plankton of the Illinois River (Table 2). Most of these were abundantly

[1]This species has been confused with *Schizocerca diversicornis* by some investigators and erroneously determined as such.

distributed in all the summer collections examined from the Rock River and many were found in the other large streams discussed. The same species have been reported for the Mississippi by Galtsoff (1924) and for the San Joaquin in California by Allen (1920). They show some seasonal fluctuation, especially in the winter, and many that are never entirely absent may be termed "fluctuating predominants." Plankton organisms are comparable to terrestrial insects in their seasonal distribution. In winter some species usually persist in the adult form in small numbers. Other species exist only as eggs, resting cells, or encysted stages. Ecologically, only those which are in an active stage and influencing the community are important at this season.

Impounded Streams

Observations on the plankton of streams after damming have showed that the impounded water becomes biologically matured. In the many pools on the Rock River created by power dams, each duplicating the hydrographic conditions of a mature stream, the same species of plankton organisms were found to occur as elsewhere in the river, but much more abundantly. The diversion of a small part of the water at Rock Falls, into the Illinois-Mississippi Canal, created a body of water with the ideal conditions of a stable stream. All the disturbing features of stream study, such as fluctuations in current and level, were removed. The water flows at a slow uniform speed and constant gradient, without fluctuations of level, emptying partly into the Illinois and partly into the Mississippi. As the water proceeds down the canal, the same plankton organisms as are found in the Rock River become much more abundant, especially the cladocerans and copepods. The bottom fauna, on the other hand, according to Dr. D. H. Thompson, of the Illinois State Natural History Survey, while of the same composition as that of the river, is relatively much less abundant.

In 1922 a dam was built across the Sangamon River at Decatur, creating a lake one-half mile wide and twelve miles long, commonly known as Lake Decatur. The water averages from six to eight feet in depth. Only at the narrow places where bridges have been constructed can any current be detected. Observations on the plankton just above the present lake showed that only a slight plankton developed when the river was low. As a result of damming the stream, stable conditions have been established and an abundant plankton produced. Since September, 1925, collections either weekly or semi-monthly have been made on the pool at Lost Bridge, two miles above the dam and ten miles below the head of the lake. Previous to 1925, collections were made there from June, 1923, until April, 1924, through the assistance of Prof. A. O.

Weese, then of James Millikin University and now of the University of Oklahoma. The temperature of the water ranged practically the same in all the years studied. In January it remained about 1° C. under the ice. Beginning in February it increased gradually and attained an average of about 28° C. in summer. In August the surface temperatures occasionally reached 30° C. The water at this point was from 15 to 20 feet deep, and the bottom temperature was always about one degree lower than the surface temperature. The pH value was rather steady throughout the year and was always well within the limits of life, generally remaining at about 7.6 and occasionally falling to 7.0 in midwinter. Dissolved oxygen determinations were made as follows:

Date	*Cubic centimeters per liter*
August 18, 1928	3.25
November 20, 1928	9.27
February 22, 1929	11.26
June 28, 1929	4.10

This showed a high content of dissolved oxygen in winter and a lower content in summer, but always an abundant supply to meet the requirements of the plankton organisms. Birge and Juday (1911) found plankton flourishing in water with 0.5 cc. of dissolved oxygen per liter and found many planktonts living very well in water with only 0.25 cc.

The plankton is abundant during the warmer months, but rather scanty during the colder months. The predominant, or prevalent, organisms (Tables 4-7) are the same as those found in the stable rivers mentioned. The greater part of the volume of the summer plankton is composed of *Diaptomus siciloides, Cyclops viridis, Cyclops bicuspidatus, Diaphanosoma brachyurum, Brachionus calyciflorus, Difflugia lobostoma,* and *Codonella cratera.* Other predominants, such as the common rotofers, *Polyarthra trigla* and *Keratella cochlearis,* although conspicuous in all the collections, do not occupy much of the volume.

The lake was one year old when the plankton was first studied. At this period there was an abundance of chlorophyl-bearing flagellates, particularly *Pleodorina illinoisensis.* Each year there was an apparent tendency toward stability (Table 19). Blue-green algae did not appear until the summer of 1926 and reappeared in the summer of 1928. The number of species of planktonts increased from year to year. The outstanding perennials, such as *Keratella cochlearis* and *Polyarthra trigla,* have persisted at all times in the collections. Others, such as *Lysigonium granulatum, Difflugia lobostoma,* and *Bosmina longirostris,* first appeared as seasonals and then became established as perennials. *Brachionus calyciflorus* and *Microcystis aeruginosa,* which appeared as perennials

in the Illinois River in 1896, 1897, and 1898, have occurred only as summer forms in Lake Decatur. Some species, such as *Asterionella gracillima,* have not yet appeared. From the fact that new species are appearing each year, it seems that the plankton has not yet reached a climax, or state of maturity, and that probably a community similar to that of a mature river is being established.

No species found in the plankton since 1923 has ever completely dropped out. Even *Pleodorina illinoisensis,* which appeared abundantly in 1923, has since occurred in small numbers, although not abundant enough to be called predominant or prevalent. This continuous progression of species is not "succession" in the same sense as this term is applied to the development of terrestrial communities, but, as will be discussed later, this progression is more comparable to invasion and colonization of a barren terrestrial area. All the predominants so far found in the plankton of Lake Decatur have been found as predominants in the Illinois River. In Lake Decatur, the absence or seasonal variation in distribution of some of the Illinois River predominants may possibly be explained by the difference in the stage of stability.

Galtsoff (1924) in his plankton survey of the upper Mississippi found that there was a great increase in the plankton of the river when it entered Lake Pepin and the lake above the Keokuk dam. In each of these places the waters were impounded over large areas, and the species were the same as elsewhere in the river, but much more abundant. Coker (1929) found that the Entomostraca of the plankton of the Mississippi River increased as the water approached the Keokuk dam.

The plankton element of mature streams may be reproduced by impounding the waters of immature streams so that they may age under more stable conditions. The waters are retained and aged under relatively stable conditions of level and reduced current—all of which are conducive to plankton development and are similar to the conditions of a large and stable stream. The impounded water, being relatively free from the disturbing fluctuations of floods, permits studies to be made that reveal seasonal trends comparable to those in a stable stream. The establishment of the plankton community in impounded waters occupies some time. Many of the species predominant in Lake Decatur in 1928 were present the second year after filling and probably were present the first. The number and abundance of species increased gradually each year until the plankton became similar to that of a stable stream.

Young Streams

In an attempt to trace the early development of plankton in young stream communities, streams ranging from 20 to 60 feet in width and

averaging from one to three feet in depth were selected. Their current-speeds ranged from two to five miles per hour, because of the relatively great fall, and were subject to sudden fluctuations. Small rapids and pools characterized their course, because of the irregular erosion of the bed. Plankton collections were made at stations from 20 to 40 miles from the source of the stream; consequently, the water was seldom over 48 hours old and generally less than 24 hours old.

During 1928, semi-monthly collections were made from the Sangamon River at Mahomet, 34 miles from its source (Table 3). Water levels at this station were relative to those recorded at Monticello (Table 9). The normal width of the stream was 50 feet, and the depth averaged 2 feet. The temperature ranged from an average of 9 degrees C. in March to 27.5 degrees C. in August. No collections were made in winter when the river was frozen over. The pH was always 7.6. The dissolved oxygen content, which was higher in summer than that of any of the other stations, ran as follows:

Date	*Cubic centimeters per liter*
August 2, 1928	11.20
November 21, 1928	9.32
February 20, 1929	8.50
June 28, 1929	4.85

Few true plankton organisms occurred in any of the collections. Occasionally a few diatoms or protozoans belonging to the bottom community were found in the collections. During the extreme low water in summer when the current was greatly reduced, a green bloom of *Euglena viridis* formed on a few pools and constituted the only evidence of abundant pelagic organisms.

During part of 1927 and all of 1928, collections were made from the Sangamon River at Monticello, 23 miles below the station at Mahomet and 57 miles below the source (Tables 8 and 9). The river at this point, though practically the same in width, was considerably deeper than at Mahomet, averaging 4 feet, but no differences could be found in the rate of flow.

Water levels (Fig. 8) were averaged monthly from readings made by the U. S. Geological Survey from a gage maintained about one mile below the station. In 1927 the river was high in March, April, May, and June, reaching a low stage in August. In 1928 a low stage was reached in May and remained until December except for several small rises. The temperature showed the usual gradual rise from 2° C. in February to about 26° C. in August. The pH seldom varied from 7.6. The dissolved oxygen determinations were as follows:

Date	Cubic centimeters per liter
August 8, 1928	3.25
November 20, 1928	9.27
February 22, 1929	11.26
June 28, 1929	4.10

The first evidence of plankton in the course of the Sangamon occurred at this point. Bottom diatoms were most abundant and, together with a few bottom Protozoa, constituted most of the plankton for December, January, and February. In summer, partly because of the seasonal reduction in the current, true planktonts appeared in small numbers. At this time, during the low water stages, many stable river perennials occurred as seasonals. The rotifer *Notholca striata* made its usual spring appearance as in the older streams and designated a scanty spring socies. The plankton, however, even in the summer was never abundant and, as the river bore true planktonts only part of the year and many of these were stable river perennials, this point in the stream may be considered as representing the stage of stream succession at which plankton production first develops.

Random collections have been made from other small and apparently young streams in Illinois, including Green River near Geneseo, Deer Creek, and Elkhorn Creek in Whiteside County, Pecatonica River at Pecatonica and Harrison, Kishwaukee River near Rockford, Leaf River near Byron, Stevens Creek near Decatur, Salt Fork at Oakwood, and also from many small streams in Wisconsin, Michigan, Colorado, and numerous other states. Few true plankton organisms occurred in any of the collections. Kofoid (1903) found that a small stream, the Spoon River, near its mouth (75-100 ft. wide) contained very little plankton. The plankton was most abundant in the summer season and consisted chiefly of Trachelomonas and Euglena. In general, small streams with a swift current contain no evidence of a definite plankton community. The development of a bottom community, however, is indicated by the mollusks and insect larvae seen in all the streams mentioned. In the succession of stream communities, the pelagic community does not appear permanently until the stream has reached some degree of stability.

Not all small streams are young or unstable. During the summer months, small sluggish streams often contain an abundant pelagic population which differs, however, from that of the more mature stream. All the streams of this type examined were dredged ditches draining swampy areas. Consequently, there was little fall, and as there was slight current, the water was much older than that of young streams of similar size and length. Vegetation was abundant in all the streams of this type examined. The Cache River in the southern part of Illinois

was studied in 1928-1929. This stream is mainly a dredged channel (30-40 feet wide, 2-4 feet deep) draining extensive cypress swamps. Usually the current is extremely sluggish; in fact, at times it cannot be detected. Seasonal collections from several points on this stream and from tributary ditches showed an abundant plankton composed largely of chlorophyl-bearing flagellates. Collections made in July, 1926, and September, 1927, from a small sluggish stream (10 feet wide, 2 feet deep) near Deer Grove, Illinois, contained numerous chlorophyl-bearing flagellates and desmids. A channel draining a swampy area west of Erie, Illinois, contained the same type of plankton. Virtually, these streams are only slowly moving shallow ponds.

CONSTITUTION OF THE PLANKTON IN LAKES AND PONDS

Lakes and ponds are bodies of water differing from each other chiefly in depth and distinguished from rivers largely by lack of current. In bodies of still water, aquatic life should reach its greatest development, as here conditions of stability are best. Various types of lakes have long been recognized as containing different types of plankton. Forel (1903) divided European lakes into three types on the basis of temperature. Marsh (1903) recognized distinct differences in the plankton of Green Lake and Lake Winnebago, and noted that deep lakes contained plankton different from that in shallow lakes. Whipple (1898) classified lakes according to amount and duration of surface and bottom temperatures. Birge and Juday (1914) classified lakes according to their respective heat budgets. Thienemann (1926) classified lakes on the basis of bottom predominants. This classification is related indirectly to that used by many European investigators who classify lakes as eutrophic, oligotrophic, and dystrophic according to the amount and origin of detritus and oxygen on the bottom. This is largely determined by depth, and the sum of these and other factors determines the predominant or prevalent species.

A study of the plankton of various types of lakes shows a classification of lakes by plankton predominants correlated to a certain extent with the classification by temperature and depth. The shallow lakes so common in central Illinois, and the moderately deep and truly deep glacial lakes farther north, have certain plankton predominants in common but differ in having others which characterize each of the various types of lakes. Without evidence from the swimming organisms and bottom socies, it is impossible to state whether these belong to three distinct

ecological communities related to one climax or whether they represent the communities of two regional climaxes of formational rank in Illinois and farther north. Temperature, largely influenced by depth and to some extent by climatic differences, seems to be the chief factor differentiating the plankton in these types of lakes. The following discussion, however, is not based primarily on physical factors but on the plankton predominants, or prevalents, which are products of the environmental factors and show ecological relations of the various communities.

Shallow Lakes and Perennial Ponds

In the study of plankton in relation to communities, it is necessary to trace its development in the communities which lead from water to land. As previously mentioned, it is possible to consider ponds and certain lakes as detached or abandoned stream areas. As the conditions in an abandoned part of a stream become more stable, the plankton increases; later when there is no longer any connection with the stream and when littoral conditions appear, the plankton declines. When parts of a stream too young to support a pelagic community are abandoned, they will, if of sufficient area and depth, reproduce the plankton element of a stable stream as far as the size will permit. Later when these parts are reduced by gradual filling by deposition and invasion of terrestrial vegetation, the plankton is supplanted by littoral organisms.

Ponds in this respect may be either detached portions of streams or else natural or artificial reproductions of abandoned areas of streams. Artificial ponds so common in our municipal parks are similar in their plankton composition to ponds of similar size cut off from streams or produced by other natural agencies. Two such ponds at Decatur and at Urbana, because of their availability, were selected for study.

The pond at Decatur was created in 1902 by damming a depression in Fairview Park. It covered nearly three acres and ranged from three to five feet in depth. Collections were made weekly most of the time from October, 1925, until December, 1928. The temperature reading showed a gradual range from nearly 2° C. in February to about 28° C. in August. The pH was generally about 7.6 in summer and sometimes as low as 6.6 in winter. The determinations for the dissolved oxygen content were as follows:

Date	*Cubic centimeters per liter*
August 19, 1928	2.51
November 24, 1928	8.14
March 3, 1929	9.22

No differences were found in bottom and surface conditions.

The pond at Urbana was created by dredging part of the abandoned channel of the West Branch of the Salt Fork in Crystal Lake Park in 1908. This pond is about one-half mile long and 75 feet wide and has an average depth of four feet. Collections were made regularly from October, 1926, until December, 1928 (Table 11). The temperature ranged from 2° C. in February to 27° C. in August. The pH varied from 7.0 in winter to 7.8 in mid-summer. The determinations for dissolved oxygen were as follows:

Date	*Cubic centimeters per liter*
August 8, 1928	2.00
November 20, 1928	5.22
February 22, 1929	7.25

In both ponds, it was usually impossible to collect during the month of January, as the ponds were used for skating and cutting of the ice was prohibited. The plankton was similar in both ponds except that *Diaptomus pallidus* was present in the Decatur pond but never in the Urbana pond. Minor differences were noted in many other organisms, but most of the abundant species considered as predominants or prevalents were the same in both ponds and were the same as those found in the plankton of stable rivers. Some forms which were perennials in Kofoid's collections from the Illinois did not show the same seasonal distribution in the park ponds. The plankton was very abundant even in winter under the ice. The dissolved salt content as indicated by dissolved chlorides ran much higher than that of the open waters such as Lake Decatur. These ponds from their lack of outlets would be expected to have a higher salt concentration than waters with open circulation.

Collections from similar artificial ponds at Inverness, Mississippi, at Neosha, Wisconsin, and at Mt. Carmel, Illinois, contained the same plankton predominants. An artificial pond near Mineral, Illinois, created in 1908 by excavating for the embankment of the Illinois-Mississippi Canal, was studied in the summers of 1926 and 1927. This pond covered about one-half acre and was not over two feet deep. The same predominants occurred as in the other artificial ponds.

Collections have been made from many natural floodplain lakes of this depth, most of them old stream oxbows, including Reelfoot Lake in Tennessee, Wolf Lake in Union County, Illinois, and numerous sloughs along the Rock River in northern Illinois (Table 15). Most of the same common predominants occurred as in the other ponds and as in the stable streams. This leads one to the conclusion that for a certain length of time after abandonment, areas of sufficient size support a mature stream population. The primary factor, undoubtedly, is the age of the water and freedom from disturbance by fluctuations in current

and level. In most of the areas studied, there was little or no outflow; consequently, the waters were not of recent origin but were old enough to support a much heavier plankton than that of the stream from which they had originated.

Kofoid found that Thompson Lake and several others on the Illinois River acted, in part at least, as supply reservoirs for the river plankton. His list of species shows no great specific difference between the lake plankton and that of the river. The lakes usually produced a more abundant plankton characterized by more abundant Entomostraca than the river, but the predominant or prevalent species were the same.

Large areas are not alone essential for the existence of the plankton of mature communities. Many small lakes of a size similar to the park ponds described above have been found to bear a plankton which differs in the absence of certain predominants, chiefly the rotifers of the genus Brachionus. These ponds contain waters of an acid nature and are surrounded by bogs or swamps. They are similar to bodies of water in the south surrounded by cypress swamps and those of the north connected with tamarack bogs. Collections were made from July, 1928, to August, 1929, on Horseshoe Lake in Alexander County, Illinois; in June, July, and August, 1927, on McIntyre Lake near Money, Mississippi (Eddy and Simer, 1928), and Macon Lake, Three Mile Lake, and Lake Dawson near Inverness, Mississippi (Table 15). All these lakes are from 5 to 15 feet deep and cover hundreds of acres. The shores are swampy and are covered with cypress trees and other vegetation which often extends 100 feet from the land. The pH ranged from 7.0 to 6.4. The plankton contained the same predominants as stable rivers with the exception of the rotifers mentioned. The latter were sometimes present, but in all collections examined they were very scarce. Harring and Myers (1928) report these rotifers as reacting unfavorably towards acidity.

The writer has not had much opportunity to examine the plankton of tamarack bog lakes, his only collections being single collections from Lake County, Illinois, Waukeshaw County, Wisconsin, and San Juan County, Washington. The water of all these lakes was more acid than could be determined on the brom-thymol blue pH indicator set carried by the writer. The water had a characteristic brown color. A "false bottom" of partially decayed organic matter was present in each lake. The plankton was fairly abundant and contained the usual prevalents with the exception of the rotifers of the genus Brachionus.

The plankton predominants cited in this paper for shallow lakes and stable rivers are largely based on studies carried on in Illinois and southern Wisconsin. Differences in predominants of such waters due to differing climates are very likely to be found in other latitudes. The

prevalent rotifers of the genus Brachionus which are so conspicuous in the Illinois and Rock River and in shallow lakes of the same vicinity are scarce or lacking in the writer's observations on southern waters (Eddy, 1931). Recent observations in central and northern Minnesota show them to be very rare in shallow lakes and large streams. If species of Brachionus are associational predominants, or prevalents, this seems to indicate a difference in predominants from north to south and suggests a change in the association.

Temporary Ponds

The successional trend of such lakes and ponds as have been previously discussed is to fill gradually until they become too shallow to hold enough water to last through periods of drought. They then become temporary ponds, containing water only during the wet seasons of the year. Vegetation, particularly button bush and willow, often invades the ponds studied at this stage.

Murray (1911) made a study of the annual distribution of the organisms of a temporary, or periodic, pond near Glasgow. The plankton and bottom fauna were mixed to such an extent that it was impossible to distinguish between them. The predominant or prevalent species were in many cases either the same as, or closely related to, those found in the ponds studied by the present writer. Prevalents appeared in the Glasgow pond almost as soon as the pond filled but did not become abundant until the water was warm.

An oxbow pond north of Urbana, Illinois, was studied in 1927 and 1928 (Table 12). This pond was one of a series left in the old channel of the West Branch of the Salt Fork by the construction of a drainage ditch in 1908. Smartweed and willow were abundant in it. When full of water it was about a foot deep and 15 feet wide by several hundred feet long. Each year it filled in October and dried up in August. During the winter months it was frozen to the bottom and no pelagic life of any kind could be found. The temperature when the pond thawed in January or February ranged from 0.5° to 3° C. and gradually increased, reaching 28° C. in August. The summer pH was around 7.6, and the winter pH was 7.4-7.1. No tests of dissolved oxygen were made, but from the amount of submerged vegetation it is very probable that this was high, at least in the warmer months.

Series of collections were made on three temporary ponds on the prairie west of Seymour, Illinois, during the wet season of 1926, through the assistance of Dr. Martha Shackelford. Also in 1928, collections were made in the largest of these ponds in the wet season (Table 13). The temperature ranged from freezing in winter to 28° C. in summer. The

shallow ponds such as this and the preceding showed more daily fluctuation in temperature than was noticed in the deeper bodies of water studied. The pH usually remained about 7.6. Only one dissolved oxygen determination was made, on November 26, 1928, when the ice was one inch thick. The reading was only 1.55 cc. per l. At that time the pond had been filled only four weeks and the vegetation had not resumed its growth. The dissolved oxygen content probably would run higher in warmer months because of the large amount of submerged vegetation.

Seasonal conditions similar to those in the Urbana pond existed here when the ponds filled in the fall. Bottom and pelagic organisms soon appeared and formed communities (Fig. 7), which later disappeared when the ponds froze solid. In late February or early March these communities again appeared with the thawing of the ice and persisted until the complete drying up in August.

All these temporary ponds contained a questionable plankton insofar as there were only a few species of true pelagic organisms. Bottom or vegetation forms were common and abundant. This aggregation of organisms should be considered, however, as they are comparable to plankton and represent the last trace of plankton before it entirely disappears as the aquatic community merges into the terrestrial community. All the different ponds agree in the presence of certain predominants. The cladoceran *Camptocercus rectirostris* and the copepod *Cyclops serrulatus* and several undetermined species of Canthocamptus are characteristic of ponds of this type only. Other prevalents which occasionally occur also in other bodies of water are various species of Simocephalus and Ceriodaphnia. *Chydorus sphaericus, Cyclops bicuspidatus, Trachelomonas volvocina, Notholca striata, Scenedesmus quadricauda, Synura uvella,* are forms which are prevalent both in temporary ponds and in mature streams. Rotifers are seldom abundant and generally consist of bottom species, especially those of the genus Monostyla. The protozoans are usually bottom forms, although chlorophyl-bearing flagellates are very abundant in summer. The same predominants were found in random collections made from temporary ponds elsewhere in Illinois, namely, at Cerro Gordo, Muncie, Erie, and Amboy.

The bottom fauna is abundant in these ponds, but with the loss of depth the pelagic society has largely disappeared. Kofoid found that, in general, waters rich in submerged macro-flora produced less plankton than those free from vegetation. Mere size has little to do with plankton production except where littoral influences creep in as the area contracts. Collections in cross-section from Lake Decatur showed no marked differences until entering the littoral areas at the shores. In this area

where the aquatic habitat merged into land, the plankton contained the same predominants as found in temporary ponds. The pelagic socies appears after the bottom socies in the developing community of a young stream and disappears before the bottom socies in the terrestrial succession of an abandoned portion of the stream. When a stream is turned into a new channel, as in the Illinois-Mississippi Canal, or when a young stream is prematurely aged, as at Decatur, the pelagic socies develops before the bottom. This is probably because the pelagic conditions essential for maturity are prepared sooner than those of the bottom.

A striking instance of the persistence of plankton in a shallow pond was found near Monticello in the summer of 1928. A few random collections were made there from a pond which was about 40 feet in diameter and 6 inches in depth, and which had a deep-mud bottom and no vegetation. Although this pond was well on its way towards becoming land, the plankton was very similar to that of larger and more permanent ponds or stable streams.

In a series of southern Illinois sink-hole ponds demonstrating succession from pond to land, the last stage, where the pond contained only 6 inches of water during the wet seasons, supported a few plankton organisms mingled with bottom forms (Eddy, 1931). A pond a foot deep showing an earlier stage, also filled only in wet seasons, retained plankton similar to that of the perennial ponds. Apparently some planktonts are very tenacious of their habitats, appearing as long as there is water to live in.

Shallow permanent ponds, located where the water table is high enough to keep them filled through the dry season, may have the same types of organisms as temporary ponds. Several such ponds, to be discussed later under succession of large lakes, were studied near Gary, Indiana. These ponds, although containing water all the year, have the same predominants as the ponds which exist only in the wet seasons. The cypress swamps in the southern part of Illinois have been studied by the writer and have been found to contain a plankton somewhat different from that of temporary ponds. The water is shallow throughout the year and filled with vegetation, but many true plankton organisms occur. Many of the prevalents are the same as those of stable streams, with the exception of the rotifers of the genus Brachionus. Chlorophyl-bearing flagellates are particularly abundant most of the year in these swamps. The rotifer *Trochosphaera aequatorialis,* which was seldom found in collections from other waters studied, is often abundant there in the summer plankton.

Deep Glacial Lakes

Although this study of plankton is based chiefly on data from the region of Illinois and the lists of community predominants apply to the waters of this region, it is of interest to consider data from other bodies of water which have, at least in part, ecological conditions similar to those of Illinois.

Numerous lakes of glacial origin, many of them very deep, are found in the northern states and Canada. Some occupy depressions in the ground moraine; others occupy depressions caused by melting of buried masses of ice left by receding ice sheets. Some occupy valleys between terminal moraines; others preglacial valleys which have been dammed by glacial deposits. Many of these lakes have outlets and tributaries.

The depth of glacial lakes varies from a few feet to several hundred feet. Many of the shallow lakes show that they were formerly quite deep and have been filled by deposition and by lowering of the water table. Extremely deep lakes, in which the temperature of the water below the thermocline shows little seasonal fluctuation, are the youngest type ecologically. As this type of lake gradually fills, the volume of the hypolimnion is reduced sufficiently for the temperature to fluctuate with the seasonal changes in the epilimnion, and it gradually changes to the shallower and warmer type of lake. Many of our moderately deep lakes undoubtedly were once very deep lakes. Juday (1914) describes many of these lakes as being extinct, having passed into marshy meadows of peat underlaid with marl.

Glacial lakes are often classified according to types of bottom (rock, clay, sand, etc.). The chemical and physical composition of the water resulting from the type of bottom or drainage area usually alters the type of plankton. The writer is inclined to believe that further study of the plankton of glacial lakes with various types of bottom and drainage basins will show that the resulting plankton communities represent stages of different seres and belong to the same regional climax. No data are presented in this paper in regard to types of bottoms and their relations to plankton communities. The glacial lakes studied by the writer were usually in sand and clay drift.

The plankton of these lakes may be divided according to predominants into two classes: that of very deep lakes, and that of shallow or moderately deep lakes. This grouping corresponds roughly with Whipple's classifications (Whipple, 1898). The deep lakes are those of the first order, and the moderately deep and shallow lakes belong to the second and third orders.

The ecological status of these lakes based on succession is very difficult to ascertain, although a study of their plankton shows that they have many characteristic organisms. Physiographically, they are not permanent, as dead or dying lakes are common throughout our northern and western states. The largest and deepest of these lakes, such as the Great Lakes, apparently are permanent, but even here we find evidence that the water has lowered and that portions of the lake have been converted into land. This process is not to be compared to the abandoning of an area by a river which, being motile, simply moves over into another area where the communities of the particular stream continue to exist.

A physiographic analysis of such lakes shows that, as they often have one or more streams entering at one end and leaving at the other, they may be considered as enlarged portions of streams (Marsh, 1903). Enlarged portions of certain large streams, such as Lake Keokuk or Lake Pepin, do not contain the same type of plankton as do these deeper glacial lakes, but retain the type of plankton found in the river. This difference may be due to depth, which in turn causes a lower and more uniform temperature in the deeper lakes.

If a stream can be matured by holding back the water as previously demonstrated, then each small stream when enlarged into a deep glacial lake should develop a replica of a mature or permanent stream community. But the tendency of any body of impounded water is to fill and to end eventually as the original stream, so that such a body is not permanent but only duplicates temporarily the conditions of a stable stream. Although very little has been done on the far northern streams of North America to determine their plankton composition, the few samples seen by the writer make it seem improbable that they bear plankton similar in specific composition to that of our deep glacial lakes.

A few random collections from the Mississippi River above Minneapolis, however, indicate that the predominant species are not the same as those in the river farther south, but are more like those of northern glacial lakes. Diatoms are conspicuous. Rotifers are scarce, Synchaeta, Polyarthra, and Keratella being the prevalent forms. No species of Brachionus were found.

The relation of the plankton of glacial lakes to the plankton of the stable river of the same region is uncertain, largely because of lack of information regarding northern stream plankton. It is entirely possible that the plankton of these lakes bears the same relation to the plankton of the stable river as exists between the plankton communities of lakes and rivers studied farther south. Although the plankton of these lakes is essentially different from that of all streams we know, their communi-

ties still may be considered as developmental stages in stream succession. By an alternative interpretation they are edaphic mature communities, especially the Great Lakes, whose permanence will depend on local conditions. In either case they should be accorded the rank of associes.

The plankton organisms of some of these lakes, for example, Lake Michigan, Lake Erie, Finger Lakes, Green Lake, Lake Mendota, and Lake Winnebago, have been described by Ward (1896), Marsh (1903), Birge and Juday (1914, 1921, 1922), Eddy (1927), and Fish (1929). The writer has examined many random collections from glacial lakes including collections from Lake Superior at Duluth, Minnesota, Lake Winnebago and Oconomowoc Lake in Wisconsin, Douglas Lake in Michigan, Sand Lake and Long Lake in Illinois, and many lakes in Minnesota. Most of these lakes are relatively deep, and many have a thermocline in summer. The plankton is definitely characterized by the presence of certain predominant species (Table 16) which seldom or never occur in rivers. Many but not all of the river predominants, previously described, occur in these lakes, showing an ecological relationship. The following species are common fluctuating predominants in the glacial lakes, showing some variation in abundance in the different seasons. Those with an asterisk are characteristic of the deeper lakes only.

Protozoa

Difflugia globulosa
Ceratium hirundinella
Codonella cratera
Dinobryon sertularia

Algae

Lysigonium granulatum
Asterionella gracillima
Striatella fenestrata*
Fragilaria crotonensis
Scenedesmus quadricauda
Pediastrum duplex

Cladocera

Bosmina longispina*
Daphnia retrocurva*
Daphnia longispina
  var. hyalina*
Chydorus sphaericus

Rotifera

Polyarthra trigla
Keratella cochlearis
Keratella quadrata
Notholca longispina*
Notholca striata
Asplanchna priodonta
Synchaeta stylata

Copepoda

Diaptomus ashlandi*
Diaptomus sicilis*
Diaptomus oregonensis
Diaptomus minutus*
Epischura lacustris*
Cyclops viridis
Cyclops bicuspidatus
Cyclops leuckarti*
Limnocalanus macrurus*

The predominants listed above show considerable variation in their distribution, not all occurring in each lake but occurring with sufficient regularity in a large proportion of the lakes examined to definitely establish their prevalence. In spite of considerable fluctuation of predominants, it is easy to distinguish two definite groups of plankton by

their predominants. Plankton containing *Striatella fenestrata, Notholca longispina, Diaptomus minutus,* and others marked with an asterisk, in addition to other predominants found in rivers and lakes alike, is usually that of a lake with a depth sufficient to keep the temperature of the water relatively low. Moderately shallow glacial lakes even with a thermocline usually do not have these deep lake prevalents, at least not in abundance, but bear a plankton which is similar to the river type, differing, however, from the river and shallow lake type previously described from Illinois by being rich in diatoms and poor in rotifers, especially *Filinia longiseta* and species of Brachionus. *Codonella cratera,* so common in rivers, is never abundant in these lakes.

The difference between these two types of glacial lakes can easily be seen by comparing the plankton of Lake Michigan and Lake Superior with that of moderately deep glacial lakes (Table 16). The plankton of Lake Michigan and Lake Superior shows some difference from the shallower glacial lakes in the predominant species of copepods, one of which, *Cyclops leuckarti,* appeared much more abundantly in the smaller lakes and in Lake Erie (Fish, 1929) but has not been reported for the other Great Lakes. In the collections examined, *Epischura lacustris* and *Diaptomus minutus* occurred more abundantly in the Great Lakes and other deep lakes.

Diaptomus sicilis and *Diaptomus ashlandi* have been reported from deep lakes only. *Diaptomus oregonensis* occurred only in the shallow glacial lakes and seemed to replace *Diaptomus pallidus* and *Diaptomus siciloides,* which are predominants in shallow lakes farther south. The rotifers *Notholca striata* and *Keratella quadrata* were present more or less sporadically throughout the year, although they occur as vernal predominants in the more shallow southern lakes.

Marsh (1903) compared the plankton of Green Lake in Wisconsin with the plankton of Lake Winnebago. Green Lake is about 7 miles long and 2½ miles wide, with a mean depth of 33.1 meters and a maximum depth of 72.2 meters, or 237 feet (Juday, 1914). Lake Winnebago is about 10 miles wide and about 28 miles long but has an average depth of only 4.7 meters with a maximum of 6.4 meters, or 21 feet. Marsh found that the plankton of Green Lake was characterized by certain organisms such as *Diaptomus sicilis, Diaptomus minutus,* and *Limnocalanus macrurus,* while Mysis and Pontoporeia were found in the abyssal portions. The plankton of Lake Winnebago was characterized by *Diaptomus oregonensis, Conochilus volvox,* and the stable river predominants *Codonella cratera, Daphnia pulex,* and *Daphnia longispina* var. *hyalina.* Many forms were common to the plankton of both lakes but

were more abundant in the deeper lake, for example, *Ceratium hirundinella, Notholca longispina, Leptodora kindtii* and *Diaphanosoma brachyurum.* This indicated that these organisms are more prevalent in deep lakes. On the other hand, many forms which are commonly found in river plankton, such as *Asplanchna, Polyarthra, Synchaeta pectinata,* and *Chydorus,* Marsh found to be more abundant in Lake Winnebago. He found also that they had a much longer season of abundance than in the deeper lakes.

In a similar way, Nordquist (1921) found it possible to distinguish the plankton of various types of Swedish waters by the predominants. He found the plankton of ponds or shallow lakes characterized by *Brachionus pala (B. calyciflorus), Brachionus urceolaris (B. capsuliflorus), Brachionus angularis, Schizocerca diversicornis, Pedalia mira, Daphnia pulex, Daphnia longispina, Ceriodaphnia pulchella,* and *Diaptomus vulgaris.* Most of these are the same species as found by the writer to be predominant in the shallow lakes and rivers discussed in this paper. Nordquist found lakes (deeper than ponds) to be characterized by *Notholca longispina, Daphnia longispina* var. *hyalina* and var. *cucullata, Bosmina coregoni, Leptodora kindtii, Cyclops oithonoides,* and *Diaptomus graciloides.* These predominants apparently determine the plankton of glacial lakes with no distinction as to deep or moderately deep glacial lakes. Many species, such as *Conochilus volvox, Asplanchna priodonta, Asplanchna brightwellii, Synchaeta pectinata, Polyarthra platyptera, Triarthra longiseta, Anuraea cochlearis, Anuraea aculeata, Diaphanosoma brachyurum, Bosmina longirostris, Cyclops strenuus, Cyclops leuckarti,* and *Diaptomus gracilis,* were found to be common to both ponds and lakes.

The plankton fauna reported by Kemmerer, Bovard, and Boorman (1923) for the deeper lakes of Washington, Oregon, California, and Idaho, contains predominants similar to those present in the northern glacial lakes. The following species appear often in the collections made by these investigators, and many probably bear the status of perennials, although the observations were limited to summer collections only.

Rotifera

Notholca longispina
Polyarthra trigla
Anuraea cochlearis
Anuraea aculeata

Cladocera

Daphnia longispina
Diaphanosoma leuchtenbergianum

Copepoda

Epischura nevadensis
Cyclops bicuspidatus
Cyclops viridis
Diaptomus oregonensis

These predominants are either the same species as, or closely related to, those found in the northern glacial lakes. The rotifer *Keratella (Anuraea) aculeata* is abundant in the spring plankton of Lake Michigan, and Kofoid also reports it as a spring form in the Illinois River. The copepod *Epischura nevadensis* replaces *Epischura lacustris* entirely in the western states. The cladoceran *Diaphanosoma leuchtenbergianum* is a questionable species and is probably the same as *Diaphanosoma brachyurum,* which occurs abundantly in the plankton of northern and eastern glacial lakes.

Collections made by Professor Frank Smith from mountain lakes in the vicinity of Tolland, Colorado, and by Professor S. A. Forbes from Yellowstone Park, were examined by the writer and found to contain in general the same type of plankton organisms as did the collections from the northern glacial lakes. The predominants from the collections from lakes in Colorado and Yellowstone Park are as follows:

Cyclops leuckarti	Diaptomus oregonensis
Cyclops viridis	Epischura nevadensis
Cyclops bicuspidatus	Diaphanosoma brachyurum
Keratella cochlearis	Daphnia longispina
Polyarthra trigla	Daphnia retrocurva
Diaptomus leptopus	Asterionella gracillima
Diaptomus shoshone	Ceratium hirundinella
Diaptomus ashlandi	

The factor of temperature has been mentioned as partly responsible for the differences in the fauna of these lakes from that of more shallow lakes or rivers in the same vicinity. Shallow lakes from which collections were made in the vicinity of Oconomowoc Lake in southern Wisconsin contained stable-river predominants, while the deeper Oconomowoc Lake itself contained both stable-river and deep-lake predominants (Table 20). Deep lakes form perhaps the most stable habitat of all fresh-water bodies. Forbes (1883) found that the conditions of life in Lake Michigan were remarkably uniform throughout the seasons and from year to year and that both plant and animal life exhibited there a regularity and stability in remarkable contrast to their fluctuations in smaller bodies of water and on land.

Shelford (Ward and Whipple, 1918) has pointed out that Lake Michigan, being a large and deep lake, has none of the seasonal temperature changes extending to the deeper parts. Consequently, as only the surface temperature fluctuates, one would expect the deeper portions to exert a greater stabilizing influence on the surrounding waters than would be found in the waters of more shallow lakes. The greatest factor, besides depth, differentiating these lakes from the shallow lakes is that of temperature. The deep lakes of Africa (West, 1907) with a high

temperature do not contain the same types of plankton organisms as found in our deep glacial lakes, but have a plankton more similar in content to that of our large rivers and shallow lakes. West mentions that this is indicative of the importance of temperature. Depth, however, is the primary factor, controlling temperature, which is a secondary factor.

Abandoned areas of glacial lakes and entire deep glacial lakes often show various stages of succession to land. A series of ponds on ridges of different ages were studied at the south end of Lake Michigan on the old Calumet beach near Gary, Indiana. In early post-glacial times, Lake Michigan occupied a much larger bed; and as the lake receded it left many beaches, the remains of which now appear as a series of sand ridges paralleling the present contour of the lake. The ponds selected for study were beyond ridges 1, 5, 14, 60, 93, 94, 95, and 96, numbered successively from the lake. These ponds are narrow, 10 to 20 feet wide, shallow and very long, extending out of sight between the ridges. Ponds 1 and 5 are comparatively free from vegetation and are about two feet deep. The other ponds range from six to twelve inches in depth and are filled with vegetation, chiefly buttonbush. The water level remains the same in the ponds throughout the year, but their general appearance is that of temporary ponds.

Collections were made in May of three years, 1927, 1928, and 1929 (Table 14). *Arcella vulgaris, Monostyla lunaris, Daphnia pulex, Cyclops serrulatus,* and species of *Simocephalus* and *Canthocamptus,* all of which are predominants characteristic of temporary ponds, were common in all the collections. Predominants such as *Chydorus sphaericus, Cyclops viridis,* and *Cyclops bicuspidatus,* which are prevalent in both temporary ponds and stable rivers, were abundant. Pond 1, nearest the lake, was polluted to some extent by a cement plant, so that the plankton may have been altered. Otherwise, the ponds nearest the lake showed evidence of their origin in the presence of a number of species which are predominant or abundant in Lake Michigan. *Ceratium hirundinella, Diaphanosoma brachyurum, Bosmina longirostris, Fragilaria crotonensis, Polyarthra trigla,* and *Keratella cochlearis* occurred in ponds 5 and 14. All these are species which are predominant in Lake Michigan and in stable rivers but not in temporary ponds. None of the species occurred which are predominant in deep lakes only and which characterize the plankton of Lake Michigan. Possibly they were unable to survive the change.

A single series of collections was made in September, 1927, from three lakes in Waukesha County, Wisconsin, (Table 20) which showed three stages of succession towards land. Although the data were scanty, they indicated the general trend of succession. The deepest and youngest was Oconomowoc Lake, which is a typical moderately deep lake

having a mean depth of 9.5 meters and a maximum depth of 19.1 meters, or 62.6 feet (Juday, 1914; Smith, 1920). Pewaukee Lake has an average depth of 3.9 meters with a maximum of 13.8 meters, or 45.3 feet. Lulu Lake, situated in the center of a large bog, represents the remains of a lake which, from the evidence of the old shore lines, formerly covered many miles and had a depth of over 80 feet. Lulu Lake is about 6 feet deep and has a soft bottom, the depth of which was not determined. This lake was acid, while the others were slightly alkaline with a pH of 7.6. The predominants of the plankton of Oconomowoc Lake were the same as for other moderately deep glacial lakes. Those of Pewaukee and Lulu lakes were more like those of stable rivers or the shallow lakes of Illinois, with the exception of the rotifers of the genus Brachionus, which did not appear in the collections. From the stage represented by Lulu Lake, the next stage of succession would be a very shallow bog pond. The data on this type of plankton, though scanty,[1] suggest that it has a succession similar to that of plankton in the abandoned channel of a stable river. Apparently, the general trend of succession of plankton in deep lakes is to that of shallow lakes and then to that of temporary ponds. *Keratella cochlearis, Polyarthra trigla,* and *Pediastrum duplex* occur as perennial predominants in the deep lakes but are not as abundant as in stable rivers. The presence of these prevalents in both types of waters indicates that these lakes occupy the status of developmental associes. The predominants characteristic of the deep glacial lakes serve to distinguish this associes from the river communities. As demonstrated by the developmental series in Oconomowoc and Lulu lakes, parts of deep lakes are similar to the ponds or abandoned areas of streams, as they also approach a terrestrial climax.

SEASONAL COMMUNITIES AS INDICATED BY PLANKTON ORGANISMS

In all the bodies of water studied throughout the seasons of the year, seasonal communities could be distinguished in the plankton by the presence of abundant organisms which may be termed "seasonals." Such communities, if mature, are usually called "societies," and if existing within an immature community they are called "socies." Seasonals should appear at certain periods and become conspicuous through their abundance or size, thus indicating the presence of a definite group of

[1]Since this work was prepared for publication, the writer has collected a large quantity of data on glacial lakes of various depths which show the same successional trend. In many cases the pond type of plankton was not reached until the lake had become very shallow.

organisms influenced, in part at least, by particular seasonal factors. Seasonals are doubtless of considerable importance, and in view of their numbers or size they must exercise some influence on other members of the community. During their absence or period of inactivity they probably exist as eggs, spores, or encysted forms.

Stable Streams and Perennial Ponds

Seasonal socies in streams are best studied under the controlled conditions produced by dams, inasmuch as the periodic floods under natural conditions may destroy or disturb the pelagic community before the plankton seasonal element has had time to develop. Even in the lake at Decatur, where the water level never fluctuated more than three feet, floods in the stream above increased the current so that the age of the water was at times reduced to that of water supporting very little plankton.

In large streams such as the Illinois River, where floods dilute the plankton but where much of the water is quite old because it has traveled from distant tributaries, seasonals still can be distinguished, although their abundance may be reduced. It was found that seasonal societies could be easily studied in undisturbed areas, such as lakes, artificial ponds, canals, or abandoned areas of streams, especially if such bodies were not subject to fluctuations of level. Such results were then compared and checked with those of a normal stream.

An attempt is made in Figs. 1-7 to represent graphically the relative volume of the seasonal, perennial, and incidental organisms composing the plankton in various types of waters for one or more years. Because of the great variations in volume, it was necessary to use a modification of the method of Lohmann as described by Birge and Juday (1922). The height of each curve represents the radius of a sphere whose volume is equal to the volume of the group of organisms. The radius may be determined by the formula, $R = \sqrt[3]{\frac{v}{4.19}}$, where v is the volume of the sphere, or in this case, the number of cubic millimeters of plankton. In order to secure graphs of convenient dimensions, it was necessary to employ a scale representing .01 cubic millimeter of plankton by a radius of .25 centimeter in Fig. 1 and .25 millimeter in Figs. 2-7. All these figures have been reduced to one-fourth the original scale for reproduction here.

Four seasonal societies or socies were found in all of the stream and pond communities studied throughout the year. The seasonal socies did not recur at the same dates in successive years, but sometimes varied as much as a month. Overlapping was a common feature, organisms

from the preceding socies persisting in small numbers for several months after their maximum abundance was past.

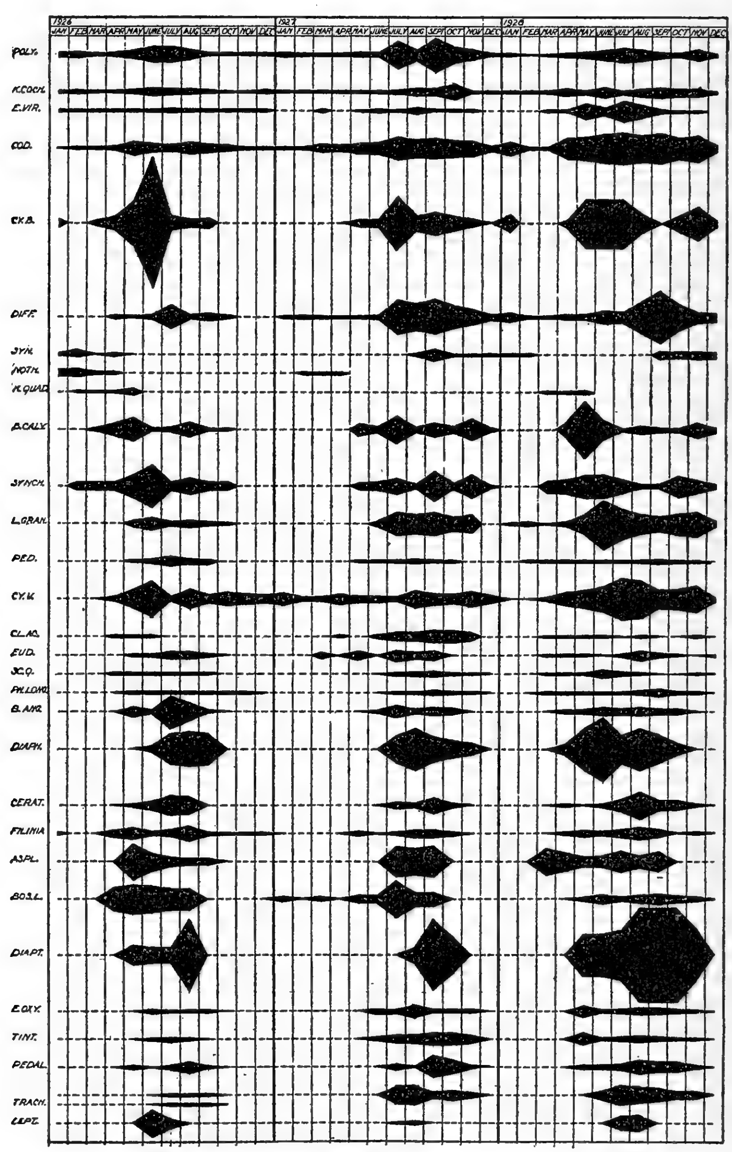

FIGURE 1

Graphs showing relative volume of predominant organisms in the plankton of Lake Decatur, 1926, 1927, 1928. (For graphical method, scale, and reduction, see text, page 37.) A key to the symbols at the left is supplied on the opposite page.

The hiemal socies usually started the last part of December and continued until April, when the vernal socies was well established. The plankton organisms of the hiemal socies were general scanty. Diatoms were common. Minute flagellates and a few ciliates, such as Stentor, were conspicuous. Perennials such as *Polyarthra trigla, Keratella cochlearis,* and *Codonella cratera* were scarce. *Synura uvella* was characteristic, often appearing late in January and remaining until April or May. Occasionally *Notholca striata* and *Cyclops bicuspidatus,* which properly belonged to the vernal socies, appeared in January, but they were never abundant or conspicuous until later in the spring. The plankton seasonals probably appear much earlier in the south than in the north, although no evidence has been published on this point. From data collected by the writer for the Illinois State Natural History Survey from Horseshoe Lake near Cairo, Illinois, 250 miles south of most of the areas reported in this paper, there is very little evidence of a hiemal socies. Hiemal forms such as *Stentor* spp. and *Synura uvella* are present during the month of January only, and the vernal socies has begun to be established by the first of February. Temperature is undoubtedly the most important factor limiting the hiemal socies. The temperature of all the waters studied in winter remained at 0.5° C. when covered with ice during January and February. Tests made through the ice always showed that there was sufficient dissolved oxygen to support plankton. The turbidity was usually low, and the pH value never fell more than slightly in winter. Light is well recognized as one important factor which is limited in winter, not only by the shorter days but also by the greater angle of incidence.

With the increase in temperature in the latter part of February, the perennials increased in abundance, and in March the seasonals of the vernal socies usually appeared. In the park ponds at Decatur and Urbana, the vernal community was well established by the end of February.

Key to Symbols Used in Fig. 1

POLY	Polyarthra trigla Ehr.	SC. Q	Scenedesmus quadricauda (Turp.) Bréb.
K. COCH	Keratella cochlearis (Gosse)	PH. LONG	Phacus longicauda (Ehr.)Duj.
COD	Codonella cratera (Leidy) Vorce	B. ANG	Brachionus angularis Gosse
CY. B	Cyclops bicuspidatus Claus	DIAPH	Diaphanosoma brachyurum (Liéven)
DIFF	Difflugia lobostoma Leidy	CERAT	Ceratium hirundinella O.F.M.
SYN	Synura uvella Ehr.	FILINIA	Filinia longiseta (Ehr.)
NOTH	Notholca striata (O.F.M.)	ASPL	Asplanchna spp.
K. QUAD	Keratella quadrata (O.F.M.)	BOS. L	Bosmina longirostris O.F.M.
B. CALY	Brachionus calyciflorus Pallas	DIAPT	Diaptomus siciloides Lillje.
SYNCH	Synchaeta spp.	E. OXY	Euglena oxyuris Schmarda
L. GRAN	Lysigonium (Melosira) granulatum (Ehr.) Kuntze	TINT	Tintinnidium fluviatilis Stein
PED	Pediastrum duplex Meyen	PEDAL	Pedalia mira (Hudson)
CY. V	Cyclops viridis Jurine	TRACH	Trachelomonas volvocina Ehr.
CL. AC	Closterium acerosum (Schrk.) Ehr.	LEPT	Leptodora kindtii (Focke)
EUD	Eudorina elegans Ehr.		

The characteristic rotifers *Keratella quadrata* and *Notholca striata* often appeared early and remained until May or June. Many of the hiemal forms persisted in small numbers through this period. *Cyclops bicus-*

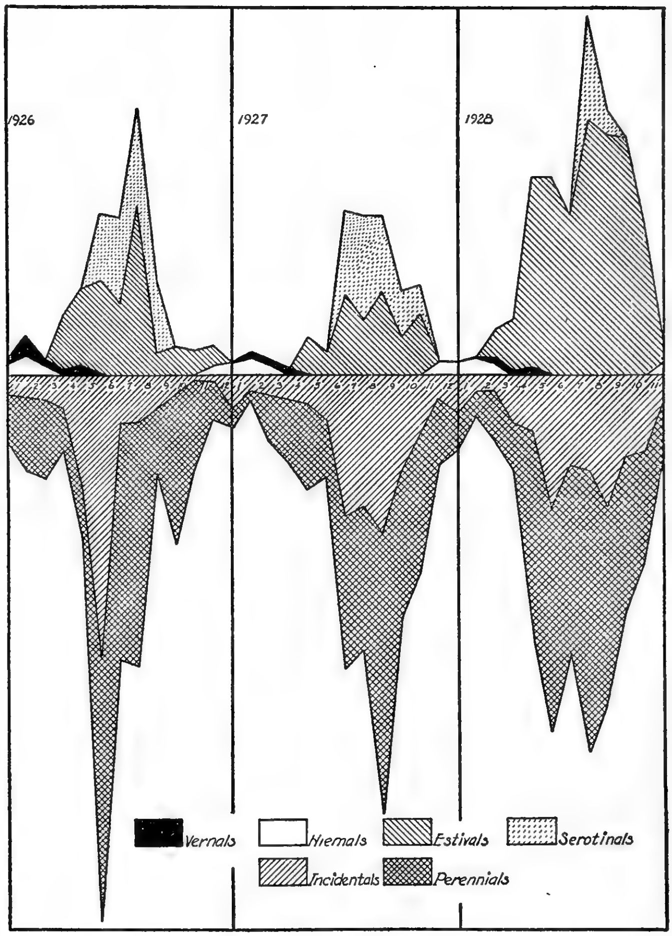

FIGURE 2

Graphs showing relative volume of principal plankton groups in Lake Decatur, 1926, 1927, and 1928. (For graphical method, scale, and reduction, see text, page 37.)

pidatus became the characteristic and abundant copepod. *Daphnia longispina, Synchaeta pectinata, Conochiloides natans, Filinia longiseta,* and *Pediastrum duplex* usually appeared at this time and persisted through the summer.

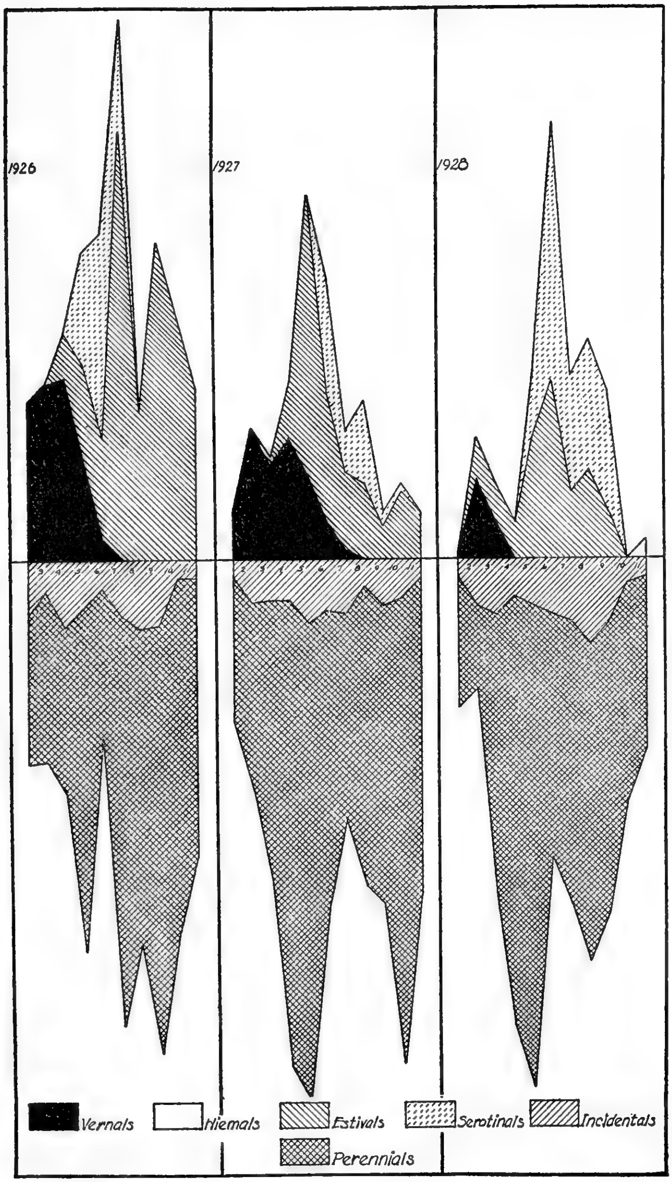

FIGURE 3

Graphs showing relative volume of principal plankton groups in the Park Pond at Decatur, 1926, 1927, and 1928. The blank spaces for January represent periods when the ice prevented collecting. (For graphical method, scale, and reduction, see text, page 37.)

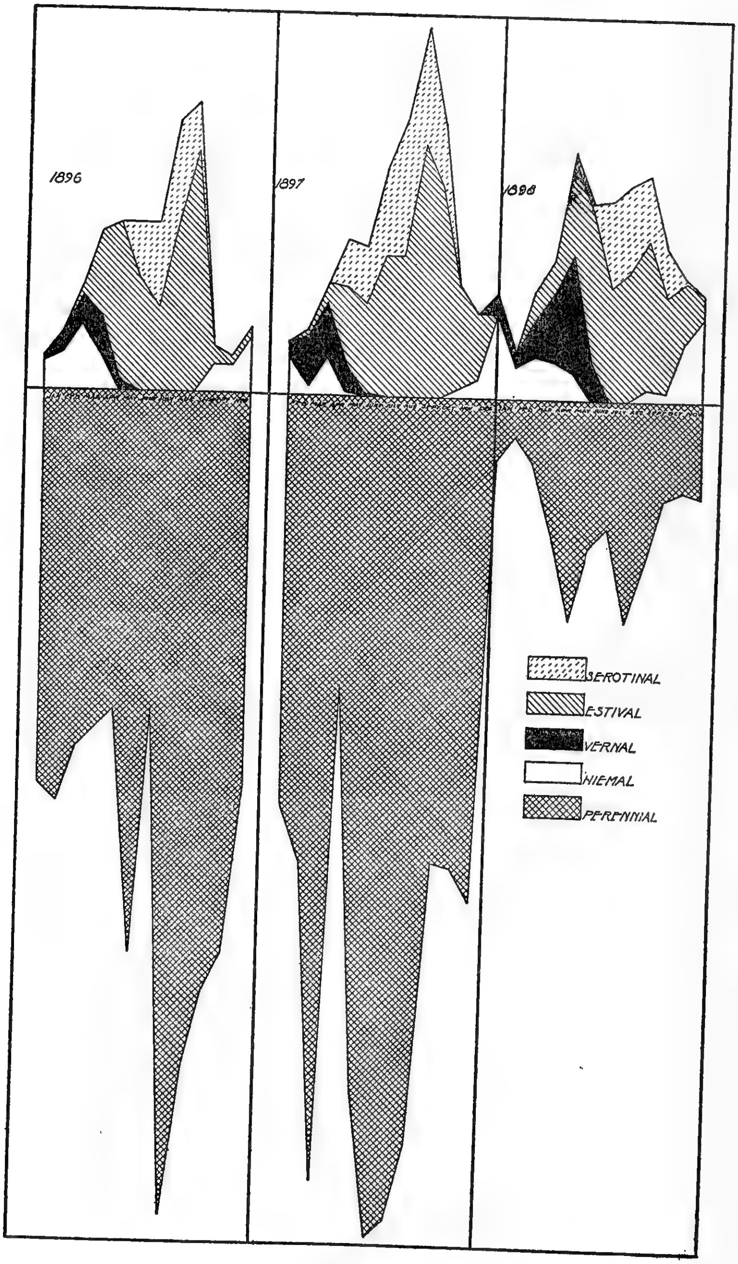

FIGURE 4

Graphs showing relative volume of principal plankton groups in the Illinois River, 1896, 1897, and 1898 (data from Kofoid). The volume of the perennial organisms was so great that it was impossible to add that of the incidental organisms. (For graphical method, scale, and reduction, see text, page 37.)

In May and June other plankton organisms appeared in abundance and formed an indefinite estival socies generally characterized by species of Brachionus. *Diaphanosoma brachyurum, Diaptomus siciloides, Diaptomus pallidus,* and many chlorophyl-bearing flagellates appeared at this time. Many of the forms present then persisted until late in the autumn.

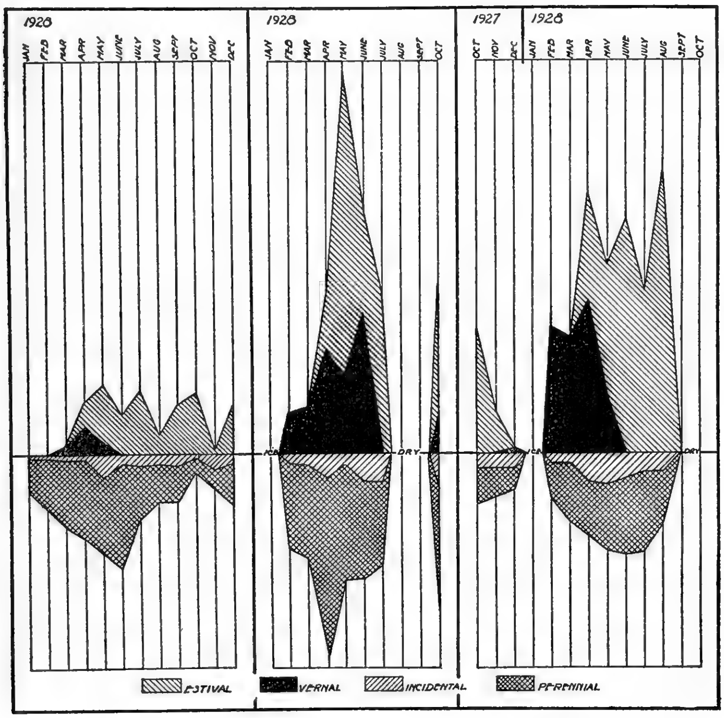

FIGURE 5 FIGURE 6 FIGURE 7

Graphs showing relative volume of principal plankton groups in three bodies of water: FIG. 5, the Sangamon River at Monticello, Illinois, 1928; FIG. 6, a temporary pond near Seymour, Illinois, 1928; FIG. 7, a temporary ox-bow pond north of Urbana, Illinois, 1927 and 1928. (For graphical method, scale, and reduction, see text, page 37.)

In July and August the plankton is usually characterized by the appearance of blue-green algae and the large cladoceran *Leptodora kindtii.* Increasing in abundance, these forms make up a serotinal community.

There is no autumnal community such as has been demonstrated for land by Weese (1924), Smith (1928), and others. The organisms present in the estival and serotinal community usually persist through the autumn

and gradually decline as the water cools, until by the end of December, when the ice forms, the hiemal community develops.

The seasonal communities for the most stable river community studied would be represented in the annual cycle of the plankton of the Illinois River. A study of Kofoid's collections and data for the years 1896, 1897, and 1898 shows that the plankton was composed of various elements (Fig. 4). The perennials, although always present, were not constant in abundance. This group formed the greater bulk of the plankton. Seasonal aspect was caused by the regular periodical appearance of certain organisms which were conspicuous enough to be termed seasonals. The remainder of the plankton was composed of organisms which appeared sporadically (incidentals); because of lack of space they are omitted from the figure.

As this represents the most stable aquatic community studied, the most conspicuous perennials and seasonals are listed here:

Perennial Predominants

Lysigonium granulatum
Microcystis aeruginosa
Pediastrum duplex
Difflugia lobostoma
Difflugia globulosa
Trachelomonas volvocina
Phacus longicauda
Codonella cratera
Polyarthra trigla
Brachionus calyciflorus
Brachionus capsuliflorus
Keratella cochlearis
Synchaeta stylata
Synchaeta pectinata
Bosmina longirostris
Cyclops bicuspidatus
Asterionella gracillima

Hiemal Predominants
(December to April)

Synura uvella
Stentor coeruleus

Vernal Predominants
(February to June)

Keratella quadrata
Notholca striata

Estival Predominants
(March to December)

Closterium acerosum
Euglena oxyuris
Euglena viridis
Brachionus angularis
Filinia longiseta
Asplanchna brightwellii
Eudorina elegans
Tintinnidium fluviatilis
Conochiloides natans
Daphnia longispina
Diaptomus pallidus
Diaptomus siciloides

Serotinal Predominants
(July to September)

Pedalia mira
Diaphanosoma brachyurum
Moina micrura
Leptodora kindtii
Euglena acus

Many plankton species are not constant in their seasonal appearance. The late vernal and the estival are difficult to distinguish, for there is a continual arrival of species during the whole period. Often one very abundant species will drop out the following year or will change place

with some other form, so that the limits of the estival are doubtful and need further investigation.

Some of the vernal predominants of the park pond at Decatur, such as *Synchaeta pectinata, Brachionus calyciflorus, Filinia longiseta,* and *Conochiloides natans,* were distinctly estival predominants in Lake Decatur.

Species of Diaptomus, because of their erratic distribution, are very unreliable as seasonal indicators. In the Illinois River and in the park pond at Decatur, *Diaptomus pallidus* appeared regularly as an estival form, but no species of this genus was found in the park pond at Urbana. *Diaptomus siciloides* appeared as an estival form occasionally in the pool of the Sangamon at Decatur and regularly in the collections of Kofoid on the Illinois River, but it never appeared during the four years observations on the park pond at Decatur.

As most of our waters are not stable, considerable shifting is to be expected. Also, immaturity of the communities causes many species to arrive later than they would in a body of older water. The plankton organisms in the writer's collections from the park ponds at Decatur and Urbana and in Kofoid's collections from the Illinois River showed much more regular distribution than the forms in Lake Decatur. The hiemal, early vernal, and serotinal communities are clearly defined by the characteristic organisms mentioned. Bennin (1926) found the annual cycle of the plankton in the Warthe to be divided into four seasonal groups as follows: February to April, May to June, July to September, October to January. These seasonal groups practically coincide with the vernal, estival, serotinal, and hiemal societies described in this paper.

Young Streams

In young streams, where plankton does not begin to develop until the water is more than a week old, the only seasonal socies discovered in the plankton is an estival socies. For example, a scanty plankton first appeared in the course of the Sangamon River at Monticello, where the age of the water was about 9 days. This plankton was present only from May until October, and was composed of many organisms which are perennial under more stable conditions farther downstream.

Temporary Ponds

Seasonal socies were hard to distinguish in the plankton element of the temporary ponds, where much of the plankton was composed of adventitious forms. No winter plankton existed, because the ponds were generally frozen solid during those months. When the ponds thawed in

February or March, many of the characteristic forms appeared and persisted until the ponds dried up in mid-summer. At this period a vernal socies can be determined by the presence of *Notholca striata.* Often other characteristic forms appeared, such as *Diaptomus sanguineus* and various species of *Eubranchipus.* Some hiemal species such as *Synura uvella,* which persist through the vernal socies in streams and perennial ponds, always occurred in the vernal socies of the temporary ponds showing that a hiemal socies would be present if it were not for the ice. The vernal forms usually disappeared in May, and except for the summer appearance of chlorophyl-bearing flagellates there were no regular or characteristic species to designate estival or serotinal socies. The ponds were usually dry in August and September, filling again in October. Within two weeks after filling, most of the forms present before drying up were again abundant and remained until the ponds froze in December. In a strict sense, there are no true perennials in these ponds, as all organisms are inactive during winter and mid-summer. The only organisms comparable to perennials are those which are present at all times when the ponds are not dry or frozen.

Glacial Lakes

The lack of seasonal data on glacial lakes makes it impossible to describe their seasonal communities definitely. Very deep lakes because of their lower and more uniform temperature throughout the year would not be expected to show much seasonal differentiation. Lake Michigan, because of its relative stability throughout the year, did not show any great seasonal differences in the plankton (Eddy, 1927). There was some indication that seasonal communities may exist in Lake Michigan from the collections made throughout the years 1887-1888 by the Illinois State Laboratory of Natural History. The occurrence of *Daphnia longispina, Diaptomus sicilis, Dinobryon sertularia, Synchaeta stylata,* and *Diaphanosoma brachyurum,* all in great abundance in summer, may indicate an estival or serotinal socies.

A study of the seasonal data of a moderately deep glacial lake as presented by Birge and Juday (1922) shows very few seasonals among the conspicuous or predominant planktonts of Lake Mendota. Most of the predominants listed are perennials, and this may be due to the fact that the seasonal conditions of such a lake do not have as wide a range as those of smaller and shallower lakes. Vernal and autumnal forms are chiefly diatoms which appear and increase after the overturn of the thermocline. Estival predominants or prevalents are chiefly algae, particularly species of Anabaena, Lyngbia, and Microcystis.

PLANKTON DEVELOPMENT AND RELATED FACTORS

The development of the plankton communities studied differs from that of terrestrial communities in that it is a steady progression rather than a succession. The water of streams is motile and to a great extent carries the pelagic community along as it flows from one stage of river conditions to another. Consequently, at any given point in the stream, the plankton is constantly shifting downward, never containing the same set of individuals for any long period of time. This means that at any fixed point, as the water flows downstream, there must be a continual production and replacement of plankton. In the course of the stream, as soon as seasonal and other conditions permit, the first plankton appears as a scanty community; as the water proceeds, this community continues to develop, adding species, all of which, if conditions remain favorable, reproduce and increase in numbers, until eventually the community approaches that of a stable stream. This is a progression of organisms rather than a succession in which one aggregation is succeeded by another entirely different.

At any given point in a stream, it is apparent that plankton develops by a series of progressive stages rather than by a succession of forms. True succession in water, in so far as plankton is concerned, depends partly on the point of view as to what constitutes an aquatic habitat. If the moving stream is considered as a continually moving habitat, always created anew at the source and continually moving downstream, then it is conceivable that true plankton succession might occur under certain conditions. Such conditions might exist in a stream, such as the Mississippi, which, flowing a great distance from north to south, passes through several sets of climatic conditions. Shifts in the climatic factors, particularly temperature, may cause some predominants to drop out and to be replaced by others, thus constituting a true succession. Further study may show, however, that such a stream passes from one aquatic climax to another.

On the other hand, if the habitat is considered as fixed along with the bottom (and there is some evidence to support this), then the development of plankton would not be in the course of the stream but at any fixed point, and here it seems to be a progression rather than a succession of predominants. Due to the fact that most streams pass through various stages of size and fall in development, it is necessary to study similar stages, found at present in the upper course, in order to determine the past development at any fixed point. However, such a series of longitudinal studies should be within the same climatic area.

In Lake Decatur as an example of newly formed bodies of water, plankton development year after year was found to be a steady progression toward a stable community. There was a progression of forms from the time the lake was first studied in 1923, when it was one year old, until 1929, when the last collections were made (Table 19). Each year a few additional species appeared, and nearly all the species showed a tendency to increase in abundance as the lake became older. No species actually disappeared, although *Pleodorina illinoisensis,* noticeably abundant in the early summer of 1923, was never found to be abundant in following years.

Plankton development is comparable to the invasion of barren areas by terrestrial forms. In waters where the plankton appears in only scanty numbers and for only a part of the year, it may be compared to plants in the desert which spring up during the rainy season. No other pelagic organisms previously occupied the waters of the streams studied, and there is no evidence that any plankton forms were actually succeeded by other planktonts. Therefore, in streams, there is no evidence of succession of plankton communities comparable to the usual succession of terrestrial communities. The only such succession was that found in the pond sere, where the water was stationary and the trend was toward a terrestrial climax. The plankton of perennial ponds containing stable-river predominants was succeeded, as the ponds approached littoral conditions, by temporary-pond plankton characterized by temporary-pond predominants. As this succession is toward a terrestrial climax, it has little significance in the development of plankton communities.

The invasion of new waters by plankton is dependent upon certain conditions which hasten or retard the development of the plankton. The most variable factors in all the waters studied by the writer were age, temperature, turbidity, and level of the water. Dissolved oxygen, hydrogen-ion concentration, and light, although varying more or less in the different seasons, were always well within the limits of plankton requirements. Other chemical factors, though not yet accurately determined to any extent, probably play an important part, particularly in relation to the food supply.

Age of Water

An opportunity to study the development of plankton in relation to age of water in the course of a stream was found when the Sangamon was dammed at Decatur in 1922. The old river channel from the source to the collecting station at Lost Bridge was 89 miles long. The formation of the lake retarded the waters so that they were many days older when they reached the station than before the dam was built. By computing the age of the water at different points in the lake and stream above, and

by tracing the stage of development of the plankton, it was possible to secure data on the age of the water at which plankton production started and the age at which it became heavy.

The source of the Sangamon River is in a group of springs and ditches where the stream may be first distinguished 6 miles northwest of Fisher, Illinois. Throughout the course of the Sangamon from its source to the head of the lake at Decatur, there are constant additions from tributaries and springs. There is no information as to the exact amount of water added, but it probably is approximately as much as the water already in the stream at Fisher. Consequently, the actual age of all the water at a given point was impossible to determine accurately. One great difficulty lay in determining the velocity at which the water flowed through the lake. Because of the irregular contour, only approximate results could be secured. The lake extends 10 miles above the collecting station and contains approximately 33 times the volume of water formerly in the old river channel. Hence, the lake is theoretically equivalent to 330 miles of river channel. It is practically impossible to measure the current as in a normal river channel, because it is perceptible only in the narrowest places, where bridges have been constructed. No doubt, the water in the center of the lake moves faster than that near the shores, but because of the bends and headlands, there is considerable intermingling of shore and center waters. This was demonstrated in repeated collections in cross-sections where the only appreciable differences in the plankton content were found in the vegetation close to the shore line. The winds cause considerable wave action on the lake and serve as a factor in keeping the waters well circulated. The river channel extends for 79 miles above the head of the lake to its source. The total distance from the source to the collecting station at Lost Bridge was equivalent to 409 miles of river channel. As the velocity could not be measured in the lake it was necessary to assume that it was the same as that of the river above the lake. This was reasonable, as no appreciable difference could be found in the velocity of the river from Mahomet to the head of the lake or in the river below the lake. The velocity was measured semi-monthly during 1928 at Mahomet and Monticello. In Table 17, there is some discrepancy in the averaged gage readings and velocities because the gage readings were made daily and the velocities only semi-monthly. Occasional measurements were taken at Cerro Gordo and at Coulter's Mill just above the lake. Broomstock floats were used, and care was taken to select quiet days when there was no wind interference.

During flood stages in February, 1928, the water in the river just above the lake reached the greatest velocity recorded, 9,000 feet per

hour, and the age of the water at the Lost Bridge station on the lake was computed at 9 days and 21 hours. Usually, however, it took much longer to reach this station. The longest period, obtained by similar calculations, was 173 days and 20 hours on October 1, 1928, when the velocity in the river was 511 feet per hour. During periods of normal level, a well-developed plankton first appeared in March at Rhea's Bridge five miles below the head of the lake (Table 17). At the head of the lake only a scanty plankton occurred at the low-water stages. At Monticello from May to October, with a high temperature and low-water stage, a

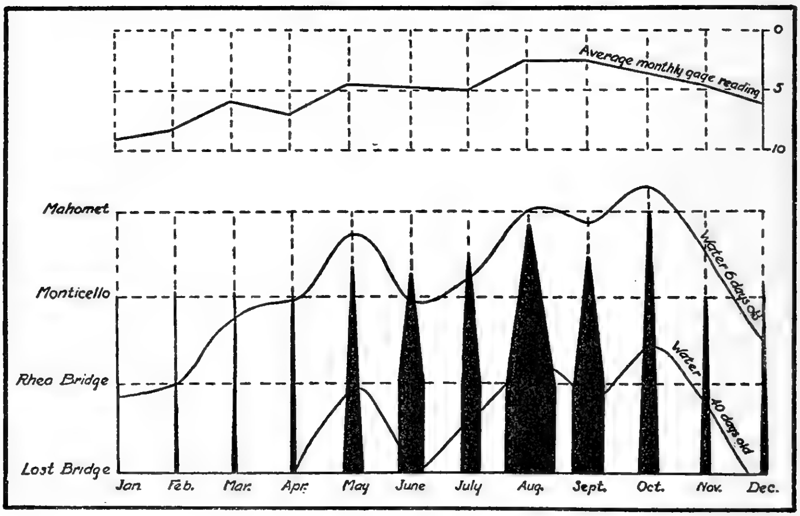

FIGURE 8

Graphs showing relation between age of water and volume of plankton at four collecting stations on the Sangamon River, 1928. Government gage readings at Monticello are plotted above the graphs of relative volume of the plankton in each month. On the same diagram are plotted two curves showing for each month the point in the stream where the water had an estimated average age of 6 days and of 40 days, respectively.

few plankton organisms were found in water averaging from 6 to 19 days old. The water was nearly always at least 20 days old before plankton organisms appeared in any abundance.

Table 18, showing the progression of organisms in the river from Mahomet to Lost Bridge, was based on the June collections of 1928. Fig. 8 shows graphically the relative volume of the plankton in the Sangamon River each month between Lost Bridge and Monticello. The age of the water and the gage reading have been plotted above showing the correlation with the distribution of plankton. Bottom diatoms and

protozoans composed most of the catch in the plankton net at Mahomet. These forms decreased as the water proceeded downward, and in about 6 days a few planktonts appeared at Monticello. When the water had reached Rhea's Bridge, about 20 days from the source, all these forms had increased in abundance, and seven new forms had appeared. At Lost Bridge, about 40 days from the source, thirteen more forms appeared, and nearly all had increased in abundance. In other months, there was some difference in the predominant species which appeared at Monticello and Rhea's Bridge, but they were never many or abundant.

According to Kofoid (1903), the Illinois River in low stage replaces its water between LaSalle and the mouth about every 23 days. The water in general at LaSalle may be safely assumed to be already about three weeks old. Therefore, most of the water at Havana, where Kofoid found abundant plankton, was at least 12 to 15 days old or more, even at flood stage, when the velocity was 9,000 feet per hour.

Schroder (1897), working on the phytoplankton of the Oder River, first described the relation of plankton to the flow of water by stating that the amount of plankton in running water of the river is in inverse proportion to the slope of the river. Consequently, as a stream approaches maturity, i.e., as it approaches a base level and its current becomes slower, there should be a proportional increase in plankton production, and this condition of maturity may be hastened by artificially retarding the waters. Similarly, the farther a stream flows from its source and the more stable its conditions tend to become, the more developed is the plankton element of the pelagic society. Kofoid from his work on the Illinois River concluded that the quantity of the plankton was, within certain limits, directly proportional to the age of the water.

Temperature

The fluctuation of river temperature constitutes one of the most marked evidences of climatic changes. The temperature runs through the same general annual cycle year after year with only minor or local variations. Temperature probably affects planktonts by retarding or accelerating their growth and reproduction (Kofoid, 1903), and it is partly responsible for the seasonal fluctuations in their abundance. Temperature also affects planktonts by causing variations in viscosity and density (Wesenberg-Lund, 1908). In the tropics (Van Oye, 1926) where a more uniform temperature prevails throughout the year, temperature does not play an important part as a seasonal factor in plankton abundance.

Water communities do not exhibit the extreme seasonal fluctuations to which land communities are subject. The seasonal change is gradual, with but little fluctuation. The waters of large streams, lakes, and ponds

studied by the writer did not show as much daily fluctuation in temperature as was found in the temperature of the air. The deeper the water, the more uniform is the temperature from day to day. In Lake Michigan the water cooled more slowly than the air in the autumn and consequently was generally warmer; in the spring the reverse was true. Large bodies of water reach freezing temperature on the surface only, and plankton organisms underneath live at a temperature usually higher than that at which organisms live on land. Many species, such as the hiemal and vernal seasonals, show temperature preferences by becoming scarce or rare as the temperature passes certain limits. Others, chiefly the perennials, have a large degree of tolerance for temperature extremes, although they are seldom as abundant at the lower temperatures. The rate of fresh-water plankton reproduction—and consequently the abundance—at different seasons in the same body of water varies directly with the temperature. Similarly, plankton content varies in bodies of water differing in temperature, as will be discussed later. In the course of any given stream where there is little climatic variation from the source to the mouth, temperature differences are too slight to have much influence on the development of the plankton.

Velocity and Water Level

Velocity of current is one of the important factors directly influencing plankton production. Water level, in itself, is not so important in regard to plankton as is the corresponding velocity. Velocity and water level are closely related; as the water level rises the velocity increases. At any given point in a stream, fluctuations of velocity result from fluctuations in water level. Velocity is usually higher in young streams, and the consequent erosion may increase the turbity and hence reduce the intensity of light. In older streams where velocity is usually lower, the turbidity may decrease and the intensity of light increase. Turbidity, by increasing as the level is raised, actually moves the point of plankton production farther downstream. Kofoid (1903) observed that streams with great velocity usually have more phytoplanktonts than zooplanktonts, and for this he advanced the explanation that the swift current prevents the zooplanktonts from feeding but does not have so much effect on the assimilation processes of the phytoplanktonts. Allen (1920) in his studies on the San Joaquin River concluded that water currents above a very moderate speed are inimical to plankton production. The writer has observed that small streams with a swift current, draining lakes or ponds containing an abundant plankton, carry little plankton themselves, and that what little they do carry comes originally from the source body

and tends to decrease rather than increase. Velocity is one of the important factors controlling the age of the water and corresponding conditions of stability necessary for the production of plankton. Velocity, thus, largely determines the point in a stream at which plankton production starts, and this point fluctuates up or downstream according to the velocity of the current, being farthest downstream when the velocity is highest and farthest upstream when the velocity is lowest.

Turbidity

Turbidity, an important factor in reducing light and hindering the movements of many planktonts, is partly controlled by velocity of current, as previously stated. When the current is reduced as the stream approaches stability, there is more tendency for the suspended silt to settle to the bottom. When the turbidity was high in the Sangamon above Lake Decatur, there was a gradual reduction as the water travelled through the lake until at Lost Bridge the turbidity was seldom noticeable, and the plankton was more abundant there than above. In all the streams studied, the turbidity due to suspended silt was highest at the flood stages of spring and summer and lowest in winter when the streams were at normal level. In summer, when the current was usually slow and there was very little suspended silt in the water, a noticeable turbidity was often caused by the increased plankton content. The turbidity in the park ponds was usually high in summer, often giving the water a very muddy appearance although it was due entirely to the heavy plankton content. Suspended silt was practically absent from these ponds because of the lack of disturbing current. In all waters a high turbidity due to suspended silt retards plankton development, and the velocity and other conditions must be such as to reduce this turbidity to proper value before plankton production can be heavy.

Light

Light, another important factor in plankton existence, especially in regard to the chlorophyl-bearing forms, has long been regarded as one of the factors limiting the vertical distribution of plankton. Aside from the differences produced by turbidity, depth, and seasons, light conditions were normal or about the same in most of the waters studied. The length of days in different seasons probably influences plankton abundance and may influence the appearance of seasonal predominants, particularly algae. Kofoid (1903) and Allen (1920) both observed indications of "lunar" pulses in the plankton and explained them on the basis of an increased amount of lunar light. The measurable differences, how-

ever, are too slight to be of much significance. In winter the ice reduces the amount of light in the water and no doubt is a factor in lowering plankton production. Intensity of light is reduced in the younger streams because of the silt produced by erosion. In more stable streams the settling out of the silt allows increased penetration of light and no doubt plays a very considerable, though as yet undetermined, part in the development of plankton.

Chemical Factors

Hydrogen-ion concentration was not an important factor in any water where plankton development was studied. The pH value of natural waters is indicative chiefly of relative acidity, which in turn is largely due to the relative amount of dissolved carbon dioxide, so that pH readings may be regarded as reflecting indirectly the CO_2 content (Birge and Juday, 1911; Shelford, 1929). The pH value of the water studied by the writer generally ranged from 7.8 in summer to 6.6 in winter, but the fluctuations were not always seasonal. In the park pond at Decatur and in other waters, most predominant planktons were found abundantly at all pH values within the range stated above, indicating that this range was well within the limits of tolerance for most of the planktonts studied. High hydrogen-ion concentration, such as pH 4.0, influences many planktonts, but none of the natural waters studied approached such an extreme value, except in swamps and bogs where some of the non-acid rotifers were absent. Harring and Myers (1928) note the absence of certain plankton rotifers from acid waters and state that the pH range for rotifers is as a rule from 2 to 3 units pH. No marked difference in pH values occurred in the waters of the Sangamon River at the points studied for plankton development, and evidently this factor did not play any part in plankton production in this stream.

The dissolved oxygen in the waters studied, as previously mentioned, was never found to be below the requirements of the plankton. Usually it ran higher in the colder months, since the water can hold more gases in solution at lower temperatures. As the plankton, in general, was most abundant in summer when the dissolved oxygen content was lowest, it seems that the dissolved oxygen played little part in seasonal distribution in the shallow waters. Although the writer made no studies on oxygen conditions in deep lakes in the different seasons, these conditions no doubt have more significance there, in regard to seasonal distribution, than in shallow lakes. Birge and Juday (1911) found that the dissolved oxygen content in the surface waters of Lake Mendota was sufficient at all times of the year, but in the deeper waters it was often insufficient, because of the seasonal stratification. In the study of the development of plankton

in the Sangamon River no marked differences were found in the amount of dissolved oxygen at different points in the stream, and it is reasonable to believe that this factor, being sufficient for ordinary requirements, had little influence on the development of the plankton.

Very few data are available on the dissolved salts and other substances in the waters studied. The samples that were analyzed indicated that there were considerable differences. For example, the waters of the park ponds contained more than 10 times as much chlorine in the form of chlorides as did the Sangamon River. Griffith (1923) has shown that waters free from calcium carbonate produce more desmids than waters bearing this salt. In December, 1928, the Illinois State Water Survey, at the writer's request, made chemical analyses of samples from two stations on the Sangamon River and from the park ponds at Decatur and Urbana, with results as shown below in terms of chlorine in chlorides, expressed in parts per million:

Sangamon River at Monticello	2
Lake Decatur at Lost Bridge	4
Decatur Park Pond	30
Urbana Park Pond	23

The relatively great amounts of dissolved salts indicated by these analyses of the pond waters may be partly responsible for the heavier plankton in these ponds. In general, it is probable that chemical factors play an essential part in development of plankton. Water flowing down a streambed has increasing opportunities to dissolve both organic and inorganic substances, some of which no doubt are made available as food to plankton organisms by bacterial action. Griffith (1923) concluded that the presence of plankton depends on the occurrence of suspended organic matter, the decomposition of which provides necessary food materials, and that the amount of plankton depends on the amount of products of fermentation. Pearsall (1922) showed that the plankton increases when there is an increase in certain salts and organic matter. This is in harmony with the observed fact that plankton is more abundant in natural waters of some age, which are obviously more suitable for plankton occupation than juvenile waters near their sources. The determination of the separate and combined effects of such factors is an indispensable step in understanding the phenomena of plankton production and constitutes a very important field for future investigation.

Biological Factors

Plankton development requires, first, that the water must be old enough to allow time for the planktonts to grow and reproduce, and

that in streams the current must be slow enough to enable the zooplanktonts to feed (Kofoid, 1903). Little is known about the rate of reproduction or length of time necessary for the embryological development of plankton organisms, but these biological factors certainly play some part in determining the point at which any given organisms appear in the course of a stream. Food requirements are at present little understood. Food may not be as important a factor in the distribution of plankton organisms as it is in the distribution of some terrestrial forms. Phytoplanktonts and chlorophyl-bearing zooplanktonts, for example, by utilizing raw materials, are less dependent on the food-factor than are the other zooplanktonts. Even the latter, moreover, are often found where there is little evidence of the phytoplanktonts on which it has been assumed that they feed. This indicates that they, too, may utilize other materials. In view of the present status of the question regarding the utilization of the organic content of waters by plankton organisms (Birge and Juday, 1926), the writer prefers to leave this matter for further investigation.

Interrelations of Factors

Hydrogen ion concentration and the dissolved oxygen content being usually favorable, as in the waters studied, the important factors observed in the production of plankton are temperature and velocity of the water. Temperature controls the rate of vital processes involved in growth and reproduction. Velocity of current is a factor in age of water and must allow time for the organisms to develop and multiply and possibly for suitable conditions of nutrition to be established. Slow current also permits the zooplanktonts to feed more freely. As the velocity decreases, the turbidity is lowered and more light penetrates the water to greater depths. When all these conditions are favorable, plankton production conceivably may continue to increase until it automatically checks itself, not only by exhausting the food supply, but also by causing such a high turbidity that the amount of light penetrating the water is insufficient for further growth and reproduction. This hypothesis would explain such facts as were observed in the park pond at Decatur, where extreme turbidity was caused by heavy zooplankton production and the algae, being most dependent on abundant light, were scarce. Juday and Wagner (1909) have suggested that plankton may become so abundant that it becomes detrimental to other organisms by the consumption of oxygen through decay. Also it is conceivable that the oxygen content might be depleted by the demand of super-abundant plankton to the point when it might form a check on the development of the plankton.

GEOGRAPHICAL DISTRIBUTION AND ECOLOGICAL CLASSIFICATION

Very little is known about the plankton organisms in many parts of the world. In vast areas, particularly South America and Australia, our information is limited to a few reports on several groups of plankton organisms. Daday's reports on some of the plankton organisms from Patagonia (1902) and on the fresh-water organisms of Paraguay (1905) (Lemmermann, 1910) include many forms which are predominant, or prevalent, in the waters studied in this paper. Juday (1915), in a study of some lakes in Central America, found many species which are common here. West (1909), on algae, and Playfair (1912 and 1919), on plankton and dinoflagellates, show that the plankton of Australian waters contains many of the same species in these groups as found elsewhere. Similar results are shown in the papers of Daday (1907), West (1907), and Cunnington (1920) on groups of plankton organisms from African lakes. Van Oye (1926) found a heavy stream plankton in the Ruki in Belgian Congo, which contained many of our common river predominants. Pernod and Schröter (1924) have shown that many of our predominant species of Cladocera are distributed in eastern and southern Asia. The predominants reported by Lemmermann (1907a) from the Yang-Tse-Kiang in China, although differing somewhat in species, are similar to those found in the relatively stable streams studied in this paper. Zacharias (1898, 1898a, and 1909), Lemmermann (1907b), and many workers since have contributed extensive data on the plankton of central European waters. Behning and his associates have done likewise for the Volga and its tributaries, showing the wide distribution of many of the predominants studied in this paper and the limited distribution of other species, particularly those cladocerans and copepods which are not found in America.

Wesenberg-Lund (1908), in an extensive geographical classification of plankton, shows that many species are cosmopolitan and others are strictly local. Species scattered commonly throughout the lakes of the arctic, temperate, and tropical regions include many Bacillariaceae, Cyanophyceae, Chlorophyceae, and Flagellata. Rotifers are especially conspicuous and include *Keratella cochlearis, Keratella quadrata, Polyarthra trigla, Asplanchna brightwellii, Triarthra longiseta,* species of the genus *Brachionus,* and *Pedalia mira.* Other conspicuous forms are *Daphnia longispina, Bosmina longirostris, Chydorus sphaericus, Cyclops viridis,* and *Cyclops leuckarti.* The species of the Diaptomidae especially show differentiation in different regions, but the cosmopolitan species were all found to be predominants in the waters studied in this paper.

All the conclusions reached in this paper in regard to communities are based on plankton evidence only. The question whether various aquatic communities are of formational or associational rank, cannot be answered definitely until the bottom organisms and fishes are studied in relation to communities throughout large areas. If the cosmopolitan predominants in the plankton were accepted as stenoecious species, they would indicate that there is but one fresh-water association in the world. Inasmuch, however, as the fishes—many of which are dominant—and also the bottom organisms—some of which may be dominant—do not show this wide-spread distribution, it may be better to consider the predominant fishes and bottom organisms as stenoecious species determining associational boundaries. Although without much evidence, the writer is inclined to believe that a study of the latter species will show that they define a number of aquatic associations in various parts of the world. Some investigators may consider the cosmopolitan planktonts as comparable to the wide-spread soil bacteria, algae, and protozoans (Sandon, 1927). Studies of these minor terrestrial forms, to determine their community distribution and community structure, may show that they occupy the same status on land as is occupied by plankton in water.

In view of the results of this investigation it is to be expected, in general, that an abundant and relatively permanent plankton should occur in any sluggish stream which presents the proper conditions of size, flow, and fluctuation, the other factors being favorable as in all the bodies of water studied. Such streams are:

1.—Streams in which natural obstructions render the current slow, as in the Mississippi River where Lake Pepin is formed by the delta of the Chippewa River.

2.—Streams with little fall and slow current, resulting from the occupation of ancient and well-worn preglacial channels, such as the Illinois River throughout most of its course.

3.—Streams flowing into the sea and practically at base level throughout most of their course, so that conditions are almost as stable as in large lakes.

On the other hand, streams which are at base level near their mouth only, as is the case of the Mississippi, cannot maintain a heavy plankton because the conditions in the upper part are such as to cause a heavy discharge of silt which is detrimental to plankton.

A summary of the predominant or prevalent species in the various types of waters studied is given in Table 20, showing that there are, in general, four types of plankton communities in the upper Mississippi Valley, which may be distinguished as follows:

1.—In rivers and related waters exhibiting some degree of stability, the conspicuous predominants are seven species of rotifers (four of which belong to the genus *Brachionus*, two to *Synchaeta*, and one to *Filinia*) and the cladoceran *Moina micrura*. These with other predominants characterize the pelagic society of stable rivers and the socies of related ponds and shallow lakes. In younger streams or wherever the conditions are less stable, the socies is characterized by the same species, but to a lesser degree; that is, they are not as abundant and may not all be present at the same time.

2.—In temporary ponds and littoral parts of stable waters with vegetation, the socies is characterized by the copepod *Cyclops serrulatus* and the cladocerans *Camptocercus rectirostris* and several species of *Simocephalus*. These predominants, together with other characteristic species, such as *Daphnia pulex*, *Moina brachiata*, and bottom rotifers of the genera *Monostyla* and *Lepadella*, may not all be present in a single collection, but they will appear often enough in a series of collections to give a characteristic aspect to the plankton.

3.—In deep glacial lakes the socies is characterized by predominants such as the rotifer *Notholca longispina*, the copepods *Diaptomus minutus* and *Epischura lacustris*, the cladocerans *Daphnia retrocurva* and *Bosmina longispina*, and the diatom *Striatella fenestrata*. At least three of these, and often all four, appeared in every collection examined by the writer.

4.—In moderately deep and shallow glacial lakes the pelagic socies is characterized by the copepod *Diaptomus oregonensis* and by abundant populations of pelagic diatoms and blue-green algae. The predominants characteristic of deeper glacial lakes are absent or scarce, and the plankton more nearly resembles that of stable rivers.

Analysis of the plankton of Russian waters as described by Behning (1913, 1921, 1926) and of many other European waters as described by a large number of investigators in the past forty years, shows these same general groups of plankton communities characterized by the same predominants. Certain predominants, such as *Cyclops viridis*, *Cyclops bicuspidatus*, *Daphnia longispina*, *Notholca striata*, *Keratella cochlearis*, and *Polyarthra trigla*, are common in all three types of plankton communities. Other predominants, *Pediastrum duplex*, *Diaphanosoma brachyurum*, and *Codonella cratera*, are most abundant in stable rivers and related waters, but are also found in small numbers in other communities. All the predominants mentioned with the exception of the copepods have been found by the writer in plankton collections from similar bodies of water in many parts of the United States.

Fresh-water plankton should be classified ecologically as the pelagic stratal society or socies of the community of a stream or lake. All the plankton communities studied by the writer showed a common ecological relationship by virtue of their possession of common predominants (Table 21), some of which are seasonals and other perennials, and by virtue of their development from common or related sources. Consequently, these plankton communities are considered as belonging to an

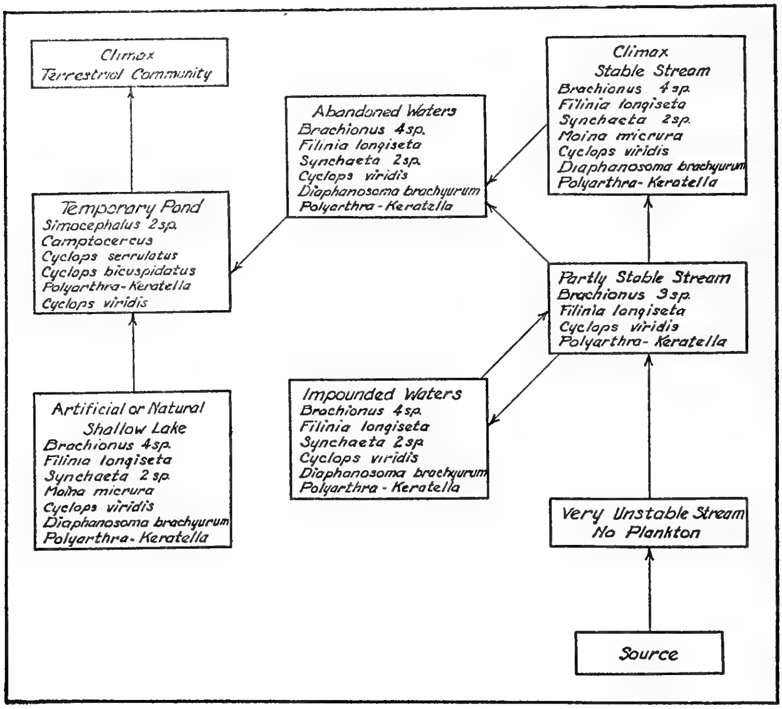

FIGURE 9

Diagram showing developmental relations and general trend of plankton communities in the region of Illinois, as characterized by some of their common predominants.

association, the climax of which is the stable-stream community. Communities other than those of stable streams either are developing toward this climax or, if they occupy abandoned areas of streams or lakes, are developing toward a terrestrial climax (Fig. 9). The Plankton of a community which is not mature, therefore, must be designated as a pelagic stratal socies rather than a society, since the latter term should be applied only to the plankton of the stable-stream community.

SUMMARY

The present study, based on more than 2,000 collections of plankton from streams, lakes, and ponds (mostly in the United States), has shown that the plankton element of fresh-water communities consists of organisms whose behavior is comparable in certain respects to that of the organisms of terrestrial communities. Some species which are conspicuous or abundant may be called predominants or prevalents, in the same sense as these terms are used for the abundant organisms of terrestrial communities. Some predominants are perennials and others seasonals. Some predominants are common in all kinds of relatively stable fresh-water communities and indicate an associational and formation-like structure comparable to that of terrestrial associations and formations, in which the predominants are of two classes, those which characterize the particular association and those which characterize the formation and serve as binding species.

In all the streams studied the plankton element gave evidence that stream communities—inasmuch as they belong to an aquatic association, the climax of which is a stable-river community—should be considered as separate from terrestrial communities.

Some predominants which are seasonal in the early stages of plankton development in a stream become perennials when the stream presents more stable conditions throughout the year.

There is a progressive development of the plankton element in streams comparable to the invasion of the barren area by terrestrial communities. This begins with the first evidence of stable conditions in the course of the stream in summer. Downstream, as the conditions become more stable, there is an increase in the number of species and the abundance of each. The most mature communities studied were found to contain about forty predominant organisms. Apparently, the number of perennials increases as the climax is approached.

The predominants in perennial ponds and shallow lakes are the same as the predominants in stable rivers. Many such ponds or lakes are abandoned parts of streams, and others which are not in any way connected with streams but contain similar predominants, may be considered as natural or artificial reproductions of abandoned parts of streams. The communities of these bodies of water are retrograding from the aquatic climax and are at some stage of succession towards a terrestrial climax and, hence, properly belong to a terrestrial association.

The last aquatic stage in the succession of pond communities toward a terrestrial climax is found in temporary ponds which contain a scanty plankton characterized by several predominants partly littoral in origin.

Three seasonal groups, or socies—hiemal, vernal, and serotinal—and possibly a fourth, estival, can be distinguished in the plankton of shallow lakes and streams of Illinois and are characterized respectively by seasonal predominants.

The important factors influencing the development of plankton are age of water (i.e., distance from source $\div$ velocity), temperature, and turbidity. In the streams studied, other factors such as light, dissolved oxygen, and hydrogen ion concentration seemed to be always sufficient to meet the requirements of the plankton. Observations on the plankton of water of different ages showed that, all other factors being favorable, a few plankton organisms usually appeared in water 6-10 days from its source, while an abundant plankton appeared in water 20 days or more from its source.

In the bodies of water studied, there are, in general, four types of plankton society or socies which may be characterized by their predominants as follows:

1.—Rivers and related waters exhibiting some degree of stability: four species of Brachionus, two of Synchaeta, *Filinia longiseta,* and *Moina micrura.*

2.—Deep lakes: *Notholca longispina, Striatella fenestrata, Daphnia retrocurva, Bosmina longispina,* and *Diaptomus minutus.*

3.—Temporary ponds: *Cyclops serrulatus, Camptocercus rectirostris,* and two species of Simocephalus.

4.—Moderately deep and shallow glacial lakes: *Diaptomus oregonensis,* pelagic diatoms, and blue-green algae.

If the vagile elements of the pelagic portion of the community and the bottom society or socies show similar differences in various areas, these aquatic communities are of associational rank.

CHECK LIST OF NAMES OF SPECIES

Key: Al=Algae; Cl=Cladocera; Co=Copepoda; Pr=Protozoa; Ro=Rotatoria.

Acroperus harpae Baird.............Cl
Alona affinis (Leydig)...............Cl
Anabaena circinalis (Kütz.) Hansg...Al
Anabaena spiroides Lemm...........Al
Anuraea aculeata Ehr. = Keratella quadrata (O.F.M.)................Ro
Anuraea cochlearis Gosse = Keratella cochlearis (Gosse)........Ro
Aphanizomenon flos-aquae (Linn.) Ralfs.............................Al
Aphanocapsa sp.....................Al
Arcella vulgaris Ehr.................Pr
Asplanchna brightwellii Gosse.......Ro
Asplanchna priodonta Gosse.........Ro
Asterionella gracillima Heiberg......Al
Bosmina coregoni Norman & Brady..Cl
Bosmina longirostris (O.F.M.).......Cl
Bosmina longispina Leydig...........Cl
Brachionus angularis Gosse.........Ro
Brachionus budapestinensis Daday...Ro
Brachionus calyciflorus Pallas.......Ro
Brachionus capsuliflorus Pallas......Ro
Brachionus havanaensis Rousselet...Ro
Brachionus patulus O.F.M...........Ro
Camptocercus rectirostris Schoedler..Cl
Canthocamptus sp...................Co
Centropyxis aculeata Stein..........Pr
Ceratium hirundinella O.F.M.........Pr
Ceriodaphnia lacustris Birge.........Cl
Ceriodaphnia pulchella Sars.........Cl
Chilodon cucullus O.F.M.............Pr
Chroococcus sp......................Al
Chydorus sphaericus (O.F.M.).......Cl
Closterium acerosum (Schrk.) Ehr...Al
Closterium moniliferum (Bory) Ehr..Al
Codonella cratera (Leidy) Vorce....Pr
Coelosphaerium naegelianum Unger..Al
Coleps hirtus Ehr...................Pr
Conochiloides natans (Sel.).........Ro
Conochilus volvox Ehr..............Ro
Cosmarium spp......................Al
Crucigenia spp......................Al
Cyclops bicuspidatus Claus.......Co
Cyclops leuckarti Claus..............Co
Cyclops oithonoides Sars............Co
Cyclops serrulatus Fischer...........Co
Cyclops strenuus Fischer............Co
Cyclops viridis Jurine...............Co
Daphnia longispina (O.F.M.)........Cl
Daphnia longispina var. cucullata Sars.............................Cl
Daphnia longispina var. hyalina Leydig............................Cl
Daphnia pulex (de Geer)............Cl
Daphnia retrocurva Forbes..........Cl
Diaphanosoma brachyurum (Liéven).Cl
Diaphanosoma leuchtenbergianum Fischer...........................Cl
Diaptomus ashlandi Marsh..........Co
Diaptomus gracilis Sars.............Co
Diaptomus graciloides Sars..........Co
Diaptomus leptopus Forbes..........Co
Diaptomus minutus Lillje...........Co
Diaptomus oregonensis Lillje........Co
Diaptomus pallidus Herrick.........Co
Diaptomus sanguineus Forbes.......Co
Diaptomus shoshone Forbes.........Co
Diaptomus sicilis Forbes............Co
Diaptomus siciloides Lillje..........Co
Diaptomus vulgaris Schmeil.........Co
Difflugia acuminata Ehr..............Pr
Difflugia globulosa Duj..............Pr
Difflugia lobostoma Leidy...........Pr
Difflugia pyriformis Perty...........Pr
Dinobryon sertularia Ehr............Pr
Epischura lacustris Forbes..........Co
Epischura nevadensis Lillje..........Co
Eudorina elegans Ehr...............Pr
Euglena acus Ehr...................Pr
Euglena acutissima Lemm............Pr
Euglena oxyuris Schmarda..........Pr
Euglena spiroides Lemm.............Pr
Euglena viridis Ehr..................Pr
Filinia longiseta (Ehr.).............Ro
Fragilaria crotonensis (Edw.) Kitton.Al
Glenodinium sp......................Pr
Gyrosigma acuminatum (Kütz.) Cl....Al
Keratella cochlearis (Gosse)........Ro
Keratella quadrata (O.F.M.)........Ro
Lecane ungulata (Gosse)............Ro
Lecquereusia epistomium Penard.....Pr
Lepadella acuminata (Ehr.).........Ro
Leptodora kindtii (Focke)...........Cl
Limnocalanus macrurus Sars........Co
Lysigonium (Melosira) granulatum (Ehr.) Kuntze....................Al
Lysigonium (Melosira) varians (Ag.)............................Al
Microcystis aeruginosa Kutz.........Al
Moina brachiata (Jurine)...........Cl
Moina micrura Kurz................Cl
Monostyla lunaris Ehr...............Ro

Navicula spp. ....Al
Nitzschia sigmoidea (Nitz.) W. Sm..Al
Notholca longispina Kellicott........Ro
Notholca striata (O.F.M.)..........Ro
Oscillatoria spp......................Al
Paramoecium bursaria Ehr..........Pr
Pedalia mira (Hudson).............Ro
Pediastrum duplex Meyen...........Al
Peridinium spp......................Pr
Peridinium tabulatum (Ehr.)........Pr
Phacus acuminata Stokes............Pr
Phacus longicauda (Ehr.) Duj.......Pr
Phacus pleuronectes (O.F.M.) Duj...Pr
Platyias quadricornis (Ehr.)........Ro
Pleodorina illinoisensis Kofoid......Pr
Pleuroxus denticulatus Birge.........Cl
Polyarthra platyptera Ehr. = Polyarthra trigla Ehr..................Ro
Polyarthra trigla Ehr................Ro
Pompholyx complanta Gosse........Ro
Scapholeberis mucronata (O.F.M.)...Cl
Scenedesmus quadricauda (Turp.) Bréb...........................Al
Simocephalus exspinosus (Koch)....Cl
Simocephalus vetulus (O.F.M.)......Cl
Sphinctocystis eliptica (Kütz.) Kuntze.Al
Sphinctocystis librilis (Ehr.) Hass...Al
Staurastrum spp.....................Al
Stentor Coeruleus Ehr...............Pr
Striatella fenestrata (Kütz.).........Al
Strombidum sp.......................Pr
Surirella robusta Ehr................Al
Synchaeta pectinata Ehr.............Ro
Synchaeta stylata Wierz.............Ro
Synedra acus (Kütz.) Gun...........Al
Synedra ulna (Nitz.) Ehr...........Al
Synura uvella Ehr...................Pr
Testudinella patina (Hermann)...Ro
Tintinnidium fluviatilis Stein........Pr
Trachelomonas hispida (Perty) Stein.............................Pr
Trachelomonas volvocina Ehr.......Pr
Triarthra longiseta Ehr. = Filina longiseta (Ehr.)..................Ro
Trichotria (Dinocharis) tetractis (Ehr.) Harring..................Ro
Trochosphaera aequatorialis Semper.Ro
Volvox globator Leeuwennoek.......Pr

TABLE 1.—ABUNDANCE OF PREDOMINANT ORGANISMS IN PLANKTON OF LARGE RIVERS
(*Thousands per cubic meter*)

Species	Rock River Sterling, Ill. Summer, 1926	Fox River Algonquin, Ill. Summer, 1916	Wabash River Mt. Carmel, Ill. April, 1927	Mississippi River St. Louis to Cairo June, 1910	Mississippi River Keokuk to St. Louis June, 1910	Ohio River Paducah to Cairo June, 1910
Trachelomonas volvocina	150.0	2.0	....	....	....	....
Difflugia lobostoma	4.1	1.7	....	1.2	1.5	10.3
Codonella cratera	144.4	8.8	1.2	.6	22.4	2.9
Bosmina longirostris	.3	.5	....	....	.1	....
Keratella cochlearis	47.6	440.0	.+	.5	15.7	.5
Brachionus calyciflorus	15.3	.3	.6	6.6	8.9	.1
Polyarthra trigla	91.1	35.2	.7	.1	6.6	.2
Synchaeta stylata	23.5	.5	.6	....	.4	....
Synchaeta pectinata	.7	.2	....	....	.+	....
Cyclops viridis	1.5	26.4	....	.7	.1	.4
Pediastrum duplex	181.7	150.0	.1	.5	42.4	3.1
Closterium acerosum	.3	1.0	....	....	.2	....
Synura uvella	....	....	.1	....	.+	....
Asterionella gracillima	45.4	....	96.0	....	37.1	....
Lysigonium granulatum	1,293.5	3,520.0	18.0	5.1	4,311.2	3.5
Chydorus sphaericus	.+	....	....	....	.+	....
Keratella quadrata	....	....	....	....	.+	....
Brachionus capsuliflorus	2.4	.4	.6	....	.2	....
Eudorina elegans	4.4	....	....	....	.+	....
Cyclops bicuspidatus	.+	.5	.2	.2	.+	....
Scenedesmus quadricauda	112.9	41.0	....	.1	2.0	.1
Euglena viridis	4.3	....	....	....	.+	....
Phacus longicauda	1.0	.8	....	....	.+	....
Tintinnidium fluviatilis	30.3	3.0	....	....	....	....
Asplanchna brightwellii	1.9	6.6	.9	....	.+	....
Filinia longiseta	2.1	2.0	.6	.2	.4	.3
Euglena oxyuris	7.4	....	....	....	.+	....
Euglena acus	1.7	....	....	....	.+	....
Diaphanosoma brachyurum	2.1	.5	....	....	.+	....
Ceratium hirundinella	36.1	8.5	....	....	.+	....
Daphnia longispina	....	....	....	.2	.+	....
Brachionus angularis	3.6	2.5	....	1.8	2.5	.2
Pedalia mira	2.0	....	....	.+	.+	....
Brachionus budapestinensis	86.2	4.0	....	.+	.+	....
Moina micrura	4.8	....	....	....	....	....
Brachionus havanaensis	.6	....	....	....	.+	....
Conochiloides natans	.3	....	....	....	....	....
Leptodora kindtii	....	....	....	....	....	....
Microcystis aeruginosa	26.2	264.0	....	....	....	....
Aphanocapsa sp.	239.8	880.0	....	....	....	....
Anabaena circinalis	104.2	660.0	....	....	....	....

+ = less than 100 per cubic meter.

TABLE 2.—MONTHLY ABUNDANCE OF PLANKTON PREDOMINANTS IN THE ILLINOIS RIVER AT HAVANA, 1896
(*Thousands per cubic meter*)

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Lysigonium granulatum	124.0	.2	96.0	531.0	3,221.0	5,500.0	4,008.0	2,820.0	463.0	657.0	136.0	5.0
Polyarthra trigla	5.6	3.8	28.7	120.7	18.8	20.0	41.5	26.7	3.7	2.0	4.8	21.0
Brachionus calyciflorus	4.0	.....	.5	295.1	6.4	.9	2.8	12.2	7.0	.4	.5	7.6
Codonella cratera	1.5	1.0	.5	198.5	23.6	50.8	2.2	19.1	23.1	63.2	2.0	1.1
Chydorus sphaericus	.3	.1	1.5	10.2	5.7	.4	+	.1	+	.1	.8	.2
Difflugia globulosa	.6	1.9	3.1	3.6	67.0	13.0	1.5	4.9	3.0	9.6	8.0	.....
Difflugia lobostoma	.2	1.3	3.2	4.6	12.2	13.6	3.0	3.1	3.6	6.8	6.8	.....
Keratella cochlearis	+	+	.2	16.3	33.8	36.2	8.3	4.7	3.7	1.2	.4	2.2
Microcystis aeruginosa	3,000.0	4,200.0	2,200.0	1,600.0	1,550.0	8,080.0	1,560.0	28,000.0	19,500.0	12,000.0	8,000.0	3,500.0
Synura uvella	54.0	73.0	391.0	124.0	.2	2.0	.7	.1	.6	53.6	60.2	299.5
Stentor coeruleus	+	.1	.3	.9	.....	.....	.1	+	.....	.....	.....	.....
Notholca striata	.2	.2	3.2	2.9	.....	.....	.....	.....	.....	.....	.....	.....
Asterionella gracillima	3.0	3.5	1.6	14,773.0	2,324.0	1.4	.....	.....	1.7	.....	.....	.....
Synchaeta stylata	3.6	29.9	113.1	36.5	.....	.....	.....	.....	.....	.....	.....	.....
Keratella quadrata	+	+	+	1.2	2.2	3.8	+	.....	.....	.....	.....	.....
Synchaeta pectinata	1.3	7.4	9.2	11.5	3.6	.4	20.7	17.6	.4	.....	.....	.....
Cyclops bicuspidatus	.....	.1	.5	.5	.....	.....	.....	.....	+	.....	.....	.3
Brachionus capsuliflorus	.....	.3	2.3	11.9	4.3	1.7	9.7	3.8	.4	.2	.9	.....
Eudorina elegans	.....	.4	3.1	6.5	2.0	+	5.0	2.0	.....	.....	.....	.....
Trachelomonas volvocina	.....	.....	2.2	.5	10.8	11.5	21.6	26.0	3.6	.....	.....	.....
Pediastrum duplex	1.2	.....	+	3.7	15.5	31.0	34.0	12.0	5.7	1.6	.4	+
Bosmina longirostris	+	.....	.....	.4	3.0	10.8	6.1	1.5	4.5	.4	2.4	.3
Cyclops viridis	.....	.....	.....	3.0	.4	.8	1.5	2.1	.5	.1	.....	.....
Closterium acerosum	.1	.....	.....	3.0	2.0	.2	.2	+	.9	.1	.....	.....
Phacus longicauda	.....	.....	.....	.1	1.1	.4	2.6	2.9	.8	.4	.4	.....
Tintinnidium fluviatilis	.....	.....	.....	.5	.3	.8	.2	1.5	1.3	.4	.....	.....
Filinia longiseta	.....	.....	.....	1.5	1.7	2.6	1.2	3.2	112.0	.....	.....	+
Asplanchna brightwellii	.....	.....	.....	.3	.6	.3	.....	.5	+	.....	.....	+
Euglena oxyuris	.....	.....	.....	7.0	.7	.....	1.0	6,833.0	25,000.0	.....	.....	.....
Euglena acus	.....	.....	.....	.1	10.0	+	.3	150.0	.....	.....	.....	.....
Diaphanosoma brachyurum	.....	.....	+	+	.....	.6	1.7	3.0	.3	.....	.....	.....
Scenedesmus quadricauda	.....	.....	.....	19.5	6.0	8.6	1.0	.3	.....	.....	.....	.....
Ceratium hirundinella	.....	.....	.....	.1	.....	7.8	+	.4	.....	.4	.....	.....
Daphnia longispina	.....	.....	.....	.8	3.5	2.8	.2	.1	.4	.....	.....	.6
Brachionus angularis	.....	.....	.....	.....	22.9	34.1	41.1	13.2	3.2	.4	.....	.....
Pedalia mira	.....	.....	.....	.....	.2	1.0	5.4	30.2	+	.....	.....	.3
Brachionus budapestinensis	.....	.....	.....	.....	.1	1.5	22.6	1.6	.7	.....	.....	.....
Brachionus havanaensis	.....	.....	.....	.....	.....	.4	.6	.6	.....	.....	.....	.....
Conochiloides natans	.....	.....	.....	.....	.....	.8	10.3	46.0	.3	.....	.....	.....
Diaptomus siciloides	+	+	.....	.....	.....	.1	.1	.0	+	.....	.....	.1
Diaptomus pallidus	+	.....	+	.....	.1	.1	.1	.4	.....	.....	.....	.....
Moina micrura	.....	.....	.....	.....	.....	.1	1.2	.....	.....	.....	.....	.....

+ = less than 100 per cubic meter.

TABLE 3.—MONTHLY ABUNDANCE OF ORGANISMS TAKEN IN PLANKTON COLLECTIONS FROM SANGAMON RIVER AT MAHOMET, 1928
(Thousands per cubic meter)

Species	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Diatoms, unidentified*	1,400.0	15,600.0	16,665.0	15,000.0	2,666.4	3,333.0	16,665.0	5,590.0	14,000.0	140.0
Navicula spp.*	.....	2,600.0	1,111.0	2,000.0	266.6	333.3	11,110.0	828.5	1,200.0	2.0
Lysigonium varians*	175.0	.....	88.0	25,000.0	13.3	235.0	.....	559.0	.....	.....
Centropyxis aculeata*	.3	.....	.4	.....	.....	.1	.....	5.6	.....	1.2
Synedra ulna*	78.5	.....	23,333.0	6,000.0	666.6	.....	.....	.....	100.0	115.0
Sphinctocystis eliptica*	.....	.....	22.2	.....	.....	.....	11.1	.....	.....	.....
Strombidum sp.*	.....	.....	44.4	.....	.....	.....	.....	.....	.....	.....
Coleps hirtus*	.....	.....	.....	40.0	.....	.....	.....	.....	.....	.....
Chilodon cucullus*	.....	.....	.....	20.0	.....	.....	.....	.....	.....	.....
Paramoecium bursaria*	.....	.....	.....	20.0	.....	.....	.....	.....	.....	.....
Cyclops viridis	.....	.....	.....	50.0	.....	.....	.....	.....	.....	.....
Gyrosigma acuminatum*	.....	.....	.....	.....	133.3	6,666.6	2,222.0	918.0	400.0	1.7
Sphinctocystis librilis*	.....	.....	.....	.....	133.3	16.6	22.2	.....	.....	15.0
Surirella robusta*	.....	.....	.....	.....	13.3	15.5	222.2	.....	.....	.....
Euglena viridis	.....	.....	.....	.....	13.3	.2	.....	.....	.....	.....
Euglena oxyuris	.....	.....	.....	.....	4.8	.....	.4	.....	5.0	.....
Oscillatoria spp.*	.....	.....	.....	.....	.....	3.0	111.1	.....	.....	.....
Closterium moniliferum	.....	.....	.....	.....	.....	.2	.....	.....	.....	.....
Arcella vulgaris	.....	.....	.....	.....	.....	+	.....	.....	.....	.....
Difflugia acuminata*	.....	.....	.....	.....	.....	.7	.....	27.9	.....	.....
Nitzschia sigmoidea	.....	.....	22.2	.....	.....	.....	222.2	.....	.....	.....
Sphinctocystis eliptica*	.....	.....	.....	.....	.....	.....	11.1	.....	.....	.....
Phacus longicauda*	.....	.....	.....	.....	.....	.....	4.4	.....	.....	.....
Cyclops serrulatus	.....	.....	.....	.....	.....	.....	.....	.5	.....	.....
Average Temperature, °C	9.0	15.0	21.0	23.5	25.0	27.5	22.0	20.0	8.3	3.0
Average pH	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6

*Decanted collections. + = less than 100 per cubic meter.

TABLE 4.—MONTHLY ABUNDANCE OF PLANKTON PREDOMINANTS IN LAKE DECATUR AT LOST BRIDGE, 1923-1924
(*Thousands per cubic meter*)

Species	June, 1923	July, 1923	Sept.,1923	Oct.,1923	Nov.,1923	Dec.,1923	Feb., 1924	Apr., 1924
Codonella cratera	124.7	1.9	221.2	192.5	562.5	1.0	.1	12.7
Difflugia lobostoma	.+	.+	26.1	2.2	.+	.+	.2	.+
Polyarthra trigla	1.0	15.0	5.1	168.7	.5	.+	....	.1
Keratella cochlearis	2.0	6.3	.8	5.0	45.0	.1	.+	.+
Lysigonium granulatum	......	136.7	3,625.0	2,000.0	4,725.0	....	....	6.2
Pediastrum duplex	27.7	1.7	5.0	2.0	123.7	....	....	.+
Asplanchna brightwellii	......	2.0	.1	.1	5.6	1.0	....	....
Synchaeta pectinata	1,081.0	2.4	1.1	3.6	45.0	2.0	....	....
Brachionus calyciflorus	24.7	2.5	2.2	4.5	....	....	....	....
Brachionus capsuliflorus	75.4	1.0	.1	1.0	12.3	....	....	....
Cyclops viridis	1,067.2	.3	4.5	....	....	....	....	....
Brachionus angularis	......	28.9	17.5	30.0	225.0	....	....	....
Eudorina elegans	22,065.1	2.6	1.0	16.8	....	....	....	....
Pleodorina illinoisensis	154.0	....	....	....	....	....	....	....
Scenedesmus quadricauda	......	3.2	1.2	2.0	5.6	....	....	....
Euglena viridis	......	27.9	23.7	73.7	225.0	....	....	....
Euglena oxyuris	......	2.6	6.8	7.2	56.2	....	....	....
Euglena acutissima	......	.+	2.0	1.0	11.2	....	....	....
Phacus longicauda	......	2.1	11.7	10.6	16.8	....	....	....
Filinia longiseta	......	9.2	.5	2.4	337.5	....	....	....
Daphnia longispina	......	3.5	7.2	1.2	....	....	.1	....
Pedalia mira	......	2.0	2.2	8.7	67.5	....	....	....
Cyclops bicuspidatus	......	....	....	1.2	11.2	.5	....	....
Ceratium hirundinella	......	....	....	....	....	....	....	....
Diaphanosoma brachyurum	......	....	....	.+	1.1	....	....	....

+ = less than 100 per cubic meter.

TABLE 5.—MONTHLY ABUNDANCE OF PLANKTON PREDOMINANTS IN LAKE DECATUR AT LOST BRIDGE, 1925-1926
(*Thousands per cubic meter*)

Species	1925 Sept.	Oct.	Nov.	Dec.	1926 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Polyarthra trigla	.1	1.7	8.9	.+	.2	1.0	.+	.3	4.3	26.5	24.0	7.0	.1	.+	.1	.+
Keratella cochlearis	.5	1.5	2.7	.6	.2	.5	.+	.+	.9	9.5	6.0	4.0	.2	.+	.+	1.2
Euglena viridis	1.5	1.9	.8	....	.1	.+	1.0	.+	.5	.4	9.0	2.1	.2	.2	.+	.1
Codonella cratera	3.0	8.0	179.8	10.0	....	.+	.+	.8	97.5	30.3	12.0	58.0	26.0	10.9	.4	.+
Synchaeta spp	....	5.5	18.5	....	....	.5	.5	.4	10.8	60.0	.6	3.0	.7	.+	....	....
Synura uvella	....	....	......	....	.3	25.0	1.0	.+	....	......	....	....	....	....	.+	....
Notholca striata	....	....	......	....	.1	1.5	.+	.+	....	......	....	....	....	....	....	....
Keratella quadrata	....	....	......	....	....	.2	.+	.+	1.0	......	....	....	....	....	....	....
Brachionus calyciflorus	.1	.5	5.0	....	....	....	.+	2.0	19.0	.+	.6	4.2	.+	.+	....	....
Cyclops bicuspidatus	....	.8	......	....	.+	....	.+	.5	20.8	400.6	.6	.1	.2	....	....	....
Cyclops viridis	1.0	52.4	......	....	....	....	....	.+	1.2	10.0	.+	1.8	.1	.4	.2	.1
Filinia longiseta	....	....	......	....	.+	....	....	4.0	13.5	.3	1.2	31.4	.1	.+	.+	.1
Difflugia lobostoma	.+	1.1	......	....	....	....	....	.2	.+	.1	30.0	47.1	.3	1.1	.4	....
Scenedesmus quadricauda	....	....	......	....	....	....	....	.+	.2	5.3	1.0	.+	.+	....	....	....
Bosmina longirostris	....	12.0	4.6	.2	....	....	....	6.0	12.7	10.0	5.0	.+	....	....	....	....
Closterium acerosum	....	....	......	....	....	....	....	.2	.2	.5	....	....	....	....	....	....
Lysigonium granulatum	20.0	489.3	1,000.4	5.0	....	....	....	....	511.5	2,270.0	60.0	343.7	50.0	7.0	....	....
Brachionus angularis	....	64.4	......	....	....	....	....	....	5.9	.8	450.0	33.1	.+	....	....	....
Asplanchna spp	....	....	......	....	....	....	....	....	11.5	1.0	.1	.1	.+	....	....	....
Eudorina elegans	....	....	......	....	....	....	....	....	.1	.3	12.0	7.5	.+	....	....	....
Ceratium hirundinella	.1	5.4	.2	....	....	....	....	....	.2	19.0	300.0	221.5	....	....	....	....
Phacus longicauda	....	....	......	....	....	....	....	....	.1	.2	.6	.4	4.0	.+	2.9	....
Pediastrum duplex	....	....	......	....	....	....	....	....	.7	9.0	108.0	9.4	.5	....	....	....
Pedalia mira	1.0	3.5	......	....	....	....	....	....	.4	.+	.6	4.1	.+	....	....	....
Diaptomus siciloides	....	4.6	3.1	....	....	....	....	....	.2	.1	.1	13.1	.+	....	....	....
Euglena oxyuris	1.0	1.0	......	....	....	....	....	....	....	1.2	.+	.3	.5	....	....	....
Diaphanosoma brachyurum	....	1.4	......	....	....	....	....	....	....	.+	1.2	1.5	1.0	....	....	....
Tintinnidium fluviatilis	2.2	3.5	1.2	....	....	....	....	....	....	.1	2.4	.+	....	....	....	....
Leptodora kindtii	....	....	......	....	....	....	....	....	....	.5	.+	....	....	....	....	....
Trachelomonas volvocina	5.0	....	......	....	....	....	....	....	....	......	.+	4.1	1.0	....	....	....
Aphanocapsa sp.	....	....	......	....	....	....	....	....	.2	.+	2.4	.1	....	....	....	....
Microcystis aeruginosa	....	....	......	....	....	....	....	....	.2	......	3.6	27.1	....	....	....	....

+ = less than 100 per cubic meter.

TABLE 6.—MONTHLY ABUNDANCE OF PLANKTON PREDOMINANTS IN LAKE DECATUR AT LOST BRIDGE, 1927
(Thousands per cubic meter)

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Difflugia lobostoma	.1	.1	+	+	+	.1	194.4	85.0	214.3	77.7	30.0	1.0
Codonella cratera*	+	+	16.7	8.0	34.5	88.8	625.6	382.6	400.0	245.5	199.9	9.0
Polyarthra trigla	.2	+	+	+	.4	.4	152.0	7.6	288.5	33.0	8.4	+
Keratella cochlearis	+	+	+	+	.1	.1	1.2	12.1	5.4	99.9	.3	+
Bosmina longirostris	+	....	+	....	.2	.1	28.1	1.0	1.1	....	.7	....
Cyclops viridis	.2	+	+	.1	+	+	+	1.1	.3	.1	.6	.1
Notholca striata	....	+	+	+	....	....	....	....	....	....	....	....
Euglena viridis	....	....	33.4	....	.1	17.7	5.5	115.0	20.0	39.9	25.0	....
Eudorina elegans	....	....	3.3	....	4.8	....	20.8	5.0	20.0	....	....	....
Synchaeta stylata	....	....	....	....	3.1	2.4	25.0	.5	114.1	.3	7.5	....
Filinia longiseta	....	....	....	....	.4	....	14.0	3.3	2.9	.1	....	....
Brachionus calyciflorus	....	....	....	....	2.2	.2	29.0	.1	4.0	.3	15.2	....
Pediastrum duplex	....	....	....	....	+	.3	3.6	4.2	5.1	1.0	1.0	....
Lysigonium granulatum	....	....	....	....	....	200.0	20,136.8	11,665.5	20,000.0	4,444.0	8,332.6	....
Brachionus angularis	....	....	....	....	....	+	8.8	.4	3.4	1.8	....	....
Daphnia longispina	+	....	+	....	....	.1	3.1	4.4	5.7	1.1	....	....
Closterium acerosum	....	....	....	.3	....	+	....	+	....	....	+	....
Tintinnidium fluviatilis*	....	....	....	....	....	16.0	76.3	83.3	200.0	237.7	65.0	....
Euglena oxyuris*	....	....	....	....	....	17.0	5.5	115.0	20.0	29.9	52.0	....
Euglena acus	....	....	....	....	....	+	+	5.0	8.5	.5	.8	....
Trachelomonas volvocina*	....	....	....	....	....	....	9,443.5	16,665.0	400.0	1,999.8	444.4	....
Ceratium hirundinella	....	....	....	....	....	....	7.1	1.2	144.0	3.7	....	....
Phacus longicauda	....	....	....	....	....	....	.1	2.3	41.3	.3	.1	....
Scenedesmus quadricauda*	....	....	....	....	....	....	63.8	66.6	400.0	22.2	66.6	....
Asplanchna brightwellii	....	....	....	....	....	....	7.5	5.0	7.3	....	....	....
Brachionus budapestinensis	....	....	....	....	....	....	15.0	10.0	3.9	.3	....	....
Brachionus havanaensis	....	....	....	....	....	....	.7	.1	.1	.1	....	....
Diaphanosoma brachyurum	....	....	....	....	....	....	.8	2.5	.5	.1	+	....
Pedalia mira	....	....	....	....	....	....	.8	....	33.1	10.0	+	....
Leptodora kindtii	....	....	....	....	....	....	.1	1.2	....	....	....	....
Synura uvella	....	....	....	....	....	....	....	+	3.9	.1	+	+
Average temperature, ° C	1.0	3.0	7.5	9.0	20.0	21.0	26.0	28.0	27.0	17.0	11.0	5.0
Average pH	7.2	7.2	7.5	7.6	7.6	7.6	7.6	7.8	7.4	7.6	7.4	7.4

*Filter paper or decanted collections. + = less than 100 per cubic meter.

TABLE 7.—MONTHLY ABUNDANCE OF PLANKTON PREDOMINANTS IN LAKE DECATUR AT LOST BRIDGE, 1928
(*Thousands per cubic meter*)

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Lysigonium granulatum*	55.5	116.6	....	150.0	9,566.8	203,873.5	43,882.6	9,999.0	6,072.5	14,252.6	22,886.6	77.7
Codonella cratera*	130.0	.2	.8	394.4	526.2	1,099.8	1,387.6	988.7	1,391.5	459.1	803.8	7.6
Difflugia lobostoma*	6.2	.+	.+	1.1	1.2	15.2	7.7	188.2	794.3	90.5	8.2	5.2
Polyarthra trigla	.+	.+	.+	.+	1.0	7.3	28.2	12.6	1.3	.1	9.5	.+
Keratella cochlearis	.1	.+	.8	6.5	2.0	22.6	.6	12.5	18.6	3.0	5.9	.+
Synura uvella	.+	.+	....	....	....	....	....	....	5.8	2.7	11.1	2.6
Pediastrum duplex	....	1.0	.+	.+	.1	2.5	.8	5.1	28.9	.2	.7	....
Keratella quadrata	....	....	.+	.1	8.7	....	....	....	....	....	....	....
Euglena viridis*	....	....	6.6	10.0	1,727.6	344.4	4,360.0	1,241.5	163.8	11.0	21.1	....
Synchaeta pectinata	....	....	1.2	2.1	....	10.8	....	....	....	.5	27.0	.1
Cyclops viridis	....	....	.+	.5	1.0	3.6	18.1	13.8	1.6	2.0	4.0	.+
Closterium acerosum	....	....	.+	.+	.+	.3	....	.+	....	....	.8	....
Eudorina elegans	....	....	.1	.1	.+	....	.+	13.6	4.6	.5	....	.1
Scenedesmus quadricauda*	....	....	3.3	.+	.1	1,107.0	43.0	.9	....	....	8.2	....
Phacus longicauda	....	....	.1	.2	4.1	.3	3.6	28.3	244.4	.5	11.1	....
Cyclops bicuspidatus	1.3	....	....	.1	31.3	31.6	18.8	1.5	....	1.1	8.9	.+
Synchaeta stylata	....	....	....	.1	62.5	2.1	9.1	.1	.2	.5	3.5	....
Brachionus calyciflorus	.1	....	....	6.6	262.0	10.0	.+	.5	.1	.1	4.5	.+
Brachionus angularis	....	....	....	.3	.9	3.2	1.1	4.2	1.5	2.2	....	....
Diaphanosoma brachyurum	....	....	....	.+	3.0	12.8	.9	2.9	.9	.+	....	....
Ceratium hirundinella*	....	....	....	.8	....	.8	75.6	799.9	463.8	57.2	1.6	....
Filinia longiseta	....	....	....	.+	1.3	1.5	5.0	13.2	4.6	1.7	....	.+
Diaptomus siciloides	....	....	....	....	2.2	2.6	3.6	40.4	37.2	36.3	5.3	....
Asplanchna brightwellii	....	....	....	....	4.5	1.0	.2	.4	2.4	.3	1.3	....
Bosmina longirostris	.1	....	....	....	.+	.1	.+	.1	.3	.1	.+	....
Euglena oxyuris*	....	....	....	....	30.0	.3	.8	6.1	2.9	.6	.1	....
Tintinnidium fluviatilis*	....	....	....	....	56.5	42.7	3,269.6	10.0	24.4	32.5	858.5	....
Pedalia mira	....	....	....	....	.3	.5	1.1	11.3	4.3	3.8	.1	....
Trachelomonas volvocina*	....	....	....	....	....	3,305.2	37,356.3	15,697.8	9,946.5	1,216.0	2,222.0	....
Brachionus havanaensis	....	....	....	....	....	.5	.+	.+	1.3	.1	....	....
Leptodora kindtii	....	....	....	....	....	....	.+	.+	....	....	....	....
Conochiloides natans	....	....	....	....	....	.1	.2	.+	.3	.4	....	....
Anabaena circinalis	....	....	....	....	....	....	....	1,200.0	1,900.0	....	....	....
Aphanocapsa sp	....	....	....	....	....	....	....	57.5	.2	....	....	....
Average temperature, ° C	1.0	4.0	7.4	9.5	21.0	22.5	26.6	28.5	14.0	13.0	5.0	22.2
Average pH	7.4	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.5	7.6	7.6	7.6

*Decanted collections. + = less than 100 per cubic meter.

Table 8.—Monthly Abundance of Plankton Predominants in Sangamon River at Monticello, 1927
(*Thousands per cubic meter*)

Species	Mar.	Apr.	May	June	July	Aug.	Nov.
Diatoms, unidentified	1.7	.5	1.0	6.8	.3	1.5	12.0
Synedra ulna	5.1	.5	.2	1.0	....	....	36.0
Difflugia lobostoma	.1	.+	.4	4.0	3.0	4.0	....
Keratella cochlearis	.1	....	....	.4	.1	.3	.2
Euglena viridis	14.0	....	....	....	2.5	....	....
Ceratium hirundinella	.+	....	....	....	.2	....	....
Bosmina longirostris	.1	....	....	....	.7	5.0	.5
Notholca striata	.+	....	....	....	....	....	....
Centropyxis aculeata	....	....	.4	.2	.1	....	.2
Navicula	....	....	....	.8	.1	.1	24.0
Daphnia longispina	....	....	....	4.0	.1	4.5	....
Cyclops bicuspidatus	....	....	....	3.0	.3	1.5	....
Pediastrum duplex	....	....	....	.2	....	3.0	.2
Phacus pleuronectes	....	....	....	....	.1	....	....
Codonella cratera	....	....	....	....	.1	1.5	....
Polyarthra trigla	....	....	....	....	.3	....	....
Brachionus havanaensis	....	....	....	....	.7	....	....
Brachionus angularis	....	....	....	....	....	3.0	....
Chydorus sphaericus	....	....	....	....	....	.2	.1
Scenedesmus quadricauda	....	....	....	....	....	.1	....
Average temperature, ° C	9.0	10.0	20.0	22.0	27.0	25.0	8.0
Average pH	7.6	7.6	7.8	7.6	7.8	7.8	7.6
Average gage readings in feet	8.5	10.9	9.3	8.5	5.4	3.8	6.6

+ = less than 100 per cubic meter.

TABLE 9.—MONTHLY ABUNDANCE OF PLANKTON PREDOMINANTS IN SANGAMON RIVER AT MONTICELLO, 1928
(*Thousands per cubic meter*)

Species	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Diatoms, unidentified*†	220.0	429.0	360.0	400.0	14,000.0	1,080.0	330.0	1,082.0	2,300.0	165.0	6,000.0	750.0
Navicula spp.*	45.0	.1	176.0	340.0	641.0	442.9	110.0	507.0	115.0	.3	2,000.0	250.0
Synedra ulna*	22.0	286.0	528.0	1,000.0	11,000.0	572.0	220.0	50.0	12.0	8.2	15.0	150.0
Difflugia lobostoma*	11.0	.5	1.0	.1	12.0	335.0	22.7	10.0	22.0	....	....	....
Centropyxis aculeata*	4.5	1.0	9.0	.6	1.0	1.5	1.0	....	....	....	....	12.0
Difflugia acuminata*	....	....	2.0	....	....	.2	11.0	1.0	1.0	....	.1	....
Polyarthra trigla	....	....	1.0	.3	.3	....	.1	....	....	....	....	....
Filinia longiseta	....	....	.3	1.0	1.0	....	....	....	....	....	....	....
Notholca striata	....	....	.1	....	.6	....	....	....	....	....	....	....
Camptocercus rectirostris	....	....	+	.6	....	....	....	....	....	....	....	....
Cyclops viridis	....	....	....	.3	.1	.5	.1	....	....	.2	....	....
Euglena viridis*	....	....	....	....	170.0	37.0	.2	101.0	231.0	165.0	.6	....
Keratella cochlearis	....	....	....	....	1.0	+	+	1.0	.2	.2	.2	....
Trachelomonas volvocina	....	....	....	....	7.5	24.0	....	281.0	23,100.0	....	....	....
Phacus acuminata*	....	....	....	....	2.0	....	....	.2	12.0	5.5	....	....
Closterium acerosum*	....	....	....	....	.1	.3	....	.2	.2	....	.5	....
Euglena oxyuris	....	....	....	....	6.0	....	....	....	....	....	....	....
Brachionus calyciflorus	....	....	....	....	.6	....	2.5	....	.1	....	....	....
Brachionus angularis	....	....	....	....	+	+	.1	....	....	.6	....	....
Brachionus havanaensis	....	....	....	....	+	....	.3	....	....	....	....	....
Codonella cratera*	....	....	....	....	7.0	....	5.0	....	....	....	....	....
Asplanchna brightwellii	....	....	....	....	1.0	....	....	....	....	.1	....	....
Daphnia longispina	....	....	....	....	.2	....	.5	....	....	.4	....	....
Bosmina longirostris	....	....	....	....	1.1	.4	.1	....	....	....	....	....
Cyclops bicuspidatus	....	....	....	....	+	.2	.1	....	....	....	....	1.5
Cyclops serrulatus	....	....	....	....	+	.1	....	.1	....	....	....	.6
Synchaeta pectinata	....	....	....	....	.1	....	....	....	....	....	....	....
Keratella quadrata	....	....	....	....	.1	....	....	....	....	....	....	....
Scenedesmus quadricauda*	....	....	....	....	....	20.0	22.0	....	....	....	....	....
Arcella vulgaris*	....	....	....	....	....	2.5	....	....	20.0	....	....	....
Brachionus capsuliflorus	....	....	....	....	....	+	.1	....	....	.1	....	....
Phacus pleuronectes*	....	....	....	....	2.0	....	....	1.0	12.0	5.5	....	....
Average temperature, ° C	4.0	2.0	6.5	13.0	17.0	22.0	24.0	26.0	23.0	20.0	8.0	5.0
Average pH	7.4	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
Average gage readings	8.3	8.7	6.0	6.9	4.6	4.7	4.9	2.4	2.4	3.5	4.4	6.0

*Decanted collections. †Mostly bottom forms. + = less than 100 per cubic meter.

TABLE 10.—MONTHLY ABUNDANCE OF PLANKTON PREDOMINANTS IN PARK POND AT DECATUR, 1927[1]
(*Thousands per cubic meter*)

Species	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Diaptomus pallidus	6.0	13.0	30.0	300.0	10.0	7.8	1.8	.4	.2	296.0	30.0
Bosmina longirostris	.1	.5	1.0	4.0	.5	125.0	5.8	.2	.1	29.6	2.0
Daphnia longispina	2.0	1.0	.4	40.0	275.0	20.0	18.5	66.0	64.0	37.0	50.0
Codonella cratera	.8	1.0	4.0	.6	600.0	382.0	270.0	6.6	400.0	1,480.0	2.0
Keratella cochlearis	1.2	14.0	34.0	350.0	530.0	216.0	49.0	44.0	108.0	74.0	46.0
Polyarthra trigla	2.0	8.0	60.0	170.0	22.0	3.0	101.0	13.2	12.0	11.1	.2
Cyclops viridis	1.0	44.0	200.0	40.0	55.0	235.0	99.5	8.8	16.0	7.9	.6
Difflugia lobostoma	.1	.+	8.0	200.0	285.0	125.0	92.5	66.0	480.0	37.0	24.0
Euglena viridis	.4	1.0	.....	.4	5.0	35.5	10.0	.1	.2	......	.1
Phacus longicauda	.8	4.0	.6	1.0	5.0	.5	1.1	.1	3.2	......	....
Chydorus sphaericus	.2	.2	2.0	.2	......	.....	.....	.4	.8	150.0	1.0
Cyclops bicuspidatus	1.0	5.0	10.0	30.0	5.0	.....	.....	.....	.....	.3	3.0
Conochiloides natans	2.0	8.0	6.0	2.0	8.0	.....	.....	.....	.....	......	....
Filinia longiseta	.2	3.0	1.2	2.0	......	.....	.....	.....	.....	......	....
Closterium acerosum	.....	6.0	1.0	.....	......	.2	1.8	.....	2.4	.1	.6
Keratella quadrata	.....	.2	.2	4.0	1.0	.....	.....	.....	.....	......	....
Brachionus calyciflorus	.....	.1	.4	.4	25.0	8.2	.1	.....	.....	......	.2
Synchaeta pectinata	.....	150.0	4.0	.....	......	.....	.....	.....	.....	......	....
Brachionus havanaensis	.....	.....	.2	.1	170.0	202.5	79.5	37.4	1.6	......	....
Asplanchna brightwellii	.....	.....	.....	4.0	15.0	7.2	1.0	3.3	.....	7.4	.8
Trachelomonas volvocina	.....	.....	.....	.....	8.0	185.0	125.0	88.0	32.0	222.0	20.0
Brachionus angularis	.....	.....	.....	.....	1.3	3.7	9.0	13.2	4.0	1.8	.1
Microcystis aeruginosa	.....	.....	.....	.....	1,000.0	52.0	.5	.4	.8	......	4.0
Ceratium hirundinella	.....	.....	.....	.....	......	624.5	3.0	.....	.4	......	....
Diaphanosoma brachyurum	.....	.....	.....	.....	......	4.4	.2	2.2	.....	......	....
Pediastrum duplex	.....	.....	.....	.....	......	6.4	13.5	13.2	4.0	11.1	.2
Scenedesmus quadricauda	.....	.....	.....	.....	......	.....	.7	2.2	1.0	......	....
Average temperature, ° C	3.5	10.0	12.0	18.5	23.0	25.0	28.0	22.5	18.0	12.0	5.0
Average pH	6.6	6.6	7.0	7.2	7.6	7.0	6.6	7.0	7.2	6.6	6.6

[1]Similar collections made in 1926 and 1928 contained the same species, except that *Pediastrum duplex* and *Scenedesmus quadricauda* were not taken in 1926, and *Phacus longicauda*, *Chydorus sphaericus*, *Cyclops bicuspidatus*, and *Brachionus angularis* were not taken in 1928. One additional species, *Brachionus capsuliflorus*, appeared in 1928.

TABLE 11.—MONTHLY ABUNDANCE OF PLANKTON PREDOMINANTS IN PARK POND AT URBANA, 1928[1]
(*Thousands per cubic meter*)

Species	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Scenedesmus quadricauda*	1,200.0	11.0	1,700.0	1,200.0	13,332.0	140,000.0	13,330.0	352.0	7,777.0	2,055.3	755.4
Trachelomonas volvocina*	1,440.0	.1	.1	3,000.0	166.6	24,200.0	8,888.0	12,000.0	6,666.0	8,221.4	1,888.7
Codonella cratera*	1,200.0	2,222.0	6,000.0	1,200.0	33.1	3,300.0	711.0	1,000.0	2,222.0	4,110.7	185.8
Polyarthra trigla	1,330.0	200.0	119.0	6.0	34.2	55.0	93.0	35.2	22.5	60.0	3.1
Bosmina longirostris	15.2	8.0	170.0	2,250.0	133.0	176.4	108.5	26.4	150.0	9.0	20.8
Asplanchna brightwellii	5.7	.2	54.4	.7	1.9	2.0	6.2	17.6	1.0	6.0	15.6
Keratella cochlearis	1.0	10.0	.6	.8	1.0	8.4	620.0	186.0	13.7	135.0	260.0
Daphnia longispina	.1	.3	7.0	1.0	57.0	54.0	......	......	11.5	6.0	2.0
Cyclops viridis	.1	2.0	30.0	28.0	10.0	252.0	387.5	220.0	115.0	60.0	20.8
Cyclops bicuspidatus	15.2	8.0	6.8	17.8	15.2	12.6	......	......	.....	.....	5.2
Brachionus calyciflorus	.1	.2	1.7	.....	.1	540.0	124.0	110.0	1.2	.....	.....
Lysigonium granulatum*	60.0	.....	40.0	.....	5,832.7	....	......	4,400.0	8,500.0	.....	.....
Pediastrum duplex*	.....	.....	13.6	90.0	1,666.5	900.0	10.0	2.0	180.0	.....	.....
Difflugia lobostoma*	.....	.....	.....	.....	16.5	165.0	533.2	2,200.0	75.0	.....	.....
Euglena viridis*	.....	.....	.....	.....	16.6	3,050.0	1.5	......	.....	.....	.....
Brachionus angularis	.....	.....	.....	.....	1.0	126.0	10.0	44.0	11.5	.....	.....
Phacus longicauda*	.....	.....	.....	.....	......	6,833.5	1,703.0	2,500.0	44.4	.....	.....
Tintinnidium fluviatilis*	.....	.....	.....	.....	......	1,000.0	177.7	1,320.0	.....	.....	.....
Conochiloides natans	.....	.....	.....	.....	......	420.0	77.5	.8	.....	.....	.....
Aphanocapsa sp.	.....	.....	.....	.....	......	....	930.0	396.0	5.0	9.0	5.2
Brachionus havanaensis	.....	.....	.....	.....	......	....	1.5	35.2	.....	.3	.....
Average temperature, ° C	20.0	6.0	10.0	18.0	22.0	25.0	26.5	16.0	11.0	6.0	3.0
Average pH	7.6	7.4	7.4	7.6	7.6	7.8	7.8	7.6	7.6	7.6	7.6

*Decanted collections. [1]Similar collections made in 1927 contained the same species except that *Brachionus calyciflorus*, *Euglena viridis*, *Phacus longicauda*, *Conochiloides natans*, *Aphanocapsa* sp., and *Brachionus havanaensis* were not taken in 1927. Two species, *Keratella quadrata* and *Chydorus sphaericus*, were taken in 1927 but not in 1928.

TABLE 12.—MONTHLY ABUNDANCE OF PLANKTON PREDOMINANTS IN OX-BOW POND NORTH OF URBANA, 1928
(*Thousands per cubic meter*)

Species	Feb.	Mar.	Apr.	May	June	July	Aug.
Navicula spp.*	175.0	280.0	4,400.0	1,266.5	100.0	300.0	17,800.0
Difflugia lobostoma	12.0	4.0	70.0	17.5	7.2	143.0	50.0
Chydorus sphaericus	.4	6.0	28.0	7.0	14.4	6.6	......
Camptocercus rectirostris	.2	.1	5.2	.3	......	......	......
Peridinium tabulatum	.2	15.0	17.5	......	......	......	......
Synura uvella*	10.0	8.0	......	......	......	......	......
Notholca striata	3.0	4.0	1.8	......	......	......	......
Simocephalus vetulus	4.0	3.0	7.0	.3	......	......	......
Cyclops serrulatus	......	......	1.0	.7	1.8	3.3	......
Cyclops bicuspidatus	......	......	1.0	.5	1.0	28.6	300.0
Cyclops viridis	......	......	17.5	35.0	9.0	8.8	......
Arcella vulgaris	......	......	.7	1.0	7.2	6.6	.5
Trachelomonas hispida*	......	......	17.8	126.6	......	......	5.4
Euglena viridis*	......	......	8.9	1.0	100.0	200.0	25,000.0
Centropyxis aculeata	......	......	1.4	.3	.1	......	......
Phacus longicauda	......	......	.3	.3	......	......	......
Daphnia longispina	......	......	.3	......	.1	4.4	......
Lepadella acuminata	......	......	1.0	......	......	......	......
Closterium acerosum	......	......	......	1.4	......	.4	20.0
Difflugia acuminata	......	......	......	3.5	.1	335.0	4.0
Cryptomonas ovata*	......	......	......	2,532.5	......	......	1,200.0
Daphnia pulex	......	......	......	.1	21.6	......	......
Keratella cochlearis	......	......	......	.1	......	......	......
Trachelomonas volvocina*	......	......	......	......	.3	660.6	880.0
Polyarthra trigla	......	......	......	......	12.6	......	9.9
Scapholeberis mucronata	......	......	......	......	54.0	35.2	......
Platyias quadricornis	......	......	......	......	.1	2.2	......
Pleuroxus denticulatus	......	......	......	......	.3	......	......
Phacus pleuronectes*	......	......	......	......	......	66.6	45.0
Brachionus patulus	......	......	......	......	......	4.4	2.0
Euglena spirogyra*	2.0	......	......	190.9	......	666.6	440.0
Eudorina elegans	......	......	......	......	......	......	178.0
Brachionus havanaensis	......	......	......	......	......	......	800.0
Average temperature, ° C.	3.0	7.0	14.0	18.0	20.0	25.0	28.0
Average pH	7.4	7.5	7.6	7.6	7.6	7.6	7.6

*Decanted collections.

TABLE 13.—MONTHLY ABUNDANCE OF PLANKTON PREDOMINANTS IN TEMPORARY POND WEST OF SEYMOUR, 1928
(*Thousands per cubic meter*)

Species	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Cyclops bicuspidatus	2.2	12.0	99.0	23.0	3.0	.2	......	......	......
Camptocercus rectirostris	1.5	.4	13.2	6.3	4.0	6.0	......	......	56.0
Diatoms, unidentified*	6,600.0	12,500.0	8,000.0	5,000.0	1,980.0	53,400.0	......	......	18,750.0
Trachelomonas volvocina*	110.0	1,000.0	2,400.0	20,000.0	26,600.0	3,560.0	......	......	1,500.0
Scenedesmus quadricauda*	11.0	50.0	160.0	25.0	20.0	18.0	......	......	......
Centropyxis aculeata	1.5	8.0	1.3	12.0	.4	1.2	......	......	.5
Difflugia lobostoma*	220.0	25.0	4.0	20.0	30.0	71.0	......	......	37.0
Difflugia acuminata	.3	4.0	.3	.5	.2	.4	......	......	......
Phacus pleuronectes	11.0	100.0	80.0	1,000.0	20,000.0	890.0	......	......	......
Notholca striata	1.5	8.0	.6	......	......	......	......	......	1.2
Synura uvella*	110.0	50.0	......	......	5,320.0	......	......	......	......
Canthocamptus sp.	.4	1.2	......	.2	......	......	......	......	1.2
Peridinium tabulatum*	1,100.0	1,500.0	24,000.0	100.0	......	......	......	......	1,125.0
Trachelomonas hispida*	10.0	100.0	320.0	3,000.0	13,300.0	26,700.0	......	......	750.0
Simocephalus vetulus	......	......	.3	54.0	......	4.0	......	......	......
Bosmina longirostris	......	......	.3	1.8	......	2.0	......	......	......
Eubranchipus sp.	......	......	.1	.1	......	......	......	......	......
Arcella vulgaris	......	......	.3	.5	......	......	......	......	......
Lecane ungulata	......	......	2.0	.2	......	6.0	......	......	......
Lepadella acuminata	......	......	30.0	20.0	......	.2	......	......	.5
Euglena viridis*	......	......	160.0	100.0	53,200.0	71,800.0	......	......	......
Euglena spiroides*	......	......	8.0	......	266.0	534.0	......	......	......
Alona affinis	......	......	......	.2	1.8	1.0	......	......	......
Testudinella patina	......	......	......	.2	.2	......	......	......	5.6
Chydorus sphaericus	......	......	......	......	......	.2	......	......	......
Average temperature, ° C.	3.0	1.0	10.0	18.0	20.0	26.0	Dry	Dry	8.0
Average pH	7.6	7.6	7.6	7.6	7.6	7.6	......	......	7.4

*Decanted collections.

TABLE 14.—ABUNDANCE OF PLANKTON PREDOMINANTS IN BEACH PONDS ON SHORE OF LAKE MICHIGAN NEAR GARY, INDIANA
Obtained from averages of collections made in May, 1927, 1928, and 1929
(*Thousands per cubic meter*)

Species	Pond 1	Pond 5	Pond 14	Pond 60	Pond 93	Pond 94	Pond 95	Pond 96
Diatoms, unidentified	82.0	260.0	5,961.3	304.0	24,000.0	240.0	567.5	1,600.0
Arcella vulgaris	.3	7.6	15.7	2.0	2.4	1.2	19.5	1.6
Peridinium tabulatum	150.0	236.6	26.1	.2	3.0	1.2	27.3	80.0
Monostyla lunaris	.4	.8	.4	.4	.6	.2	.4	.4
Daphnia pulex	.3	....	.4	.8	1.2	7.2	2.1	3.2
Cyclops viridis	3.0	.3	21.0	12.0	12.0	2.4	15.0	12.0
Ostracods, unidentified	.7	.8	30.0	6.0	12.0	.6	26.5	16.0
Chydorus sphaericus	4.5	1.3	15.4	.2	6.0	....	5.9	....
Lecquereusia epistomium	1.5	.2	7.6	....	....	....	.3	....
Ceriodaphnia sp.	6.0	2.1	3.9	.4	1.2	....	....	.4
Ceratium hirundinella*	.1	1.4	.2	....	....	....	....	....
Testudinella patina	....	.1	.2	....	....	....	....	....
Diaptomus sanguineus	....	1.1	20.0	.2	3.0	.2	2.7	.4
Cyclops bicuspidatus	....	4.7	3.6	.4	36.0	.4	6.0	8.0
Cyclops serrulatus	....	2.6	1.3	....	.1	....	2.0	....
Daphnia longispina	....	.4	.4	.4	2.4	....	14.4	....
Canthocamptus sp.	....	.1	1.0	.2	6.0	....	....	....
Trichotria tetractis	....	.2	1.3	....	1.2	.1	.8	....
Bosmina longirostris	....	5.0	....	....	....	....	....	....
Difflugia lobostoma	....	7.6	7.6	....	....	....	.2	....
Dinobryon sertularia	....	260.0	120.0	....	36.0	....	143.5	....
Difflugia pyriformis	....	.1	4.0	....	....	....	....	....
Lepadella acuminata	....	.2	3.0	....	....	....	.4	....
Closterium moniliferum	....	.2	.1	.2	....	....	.2	....
Fragilaria crotonensis*	....	2,000.0	3,600.0	4.0	....	....	....	....
Staurastrum spp.	....	.5	39.6	....	....	....	....	....
Cosmarium spp.	....	6.0	33.0	....	....	....	....	....
Crucigenia spp.	....	.4	3.6	....	....	....	....	....
Chroococcus sp.	....	.2	1.3	....	....	....	....	....
Eudorina elegans	....	.1	1.2	....	....	....	....	....
Pleuroxus denticulatus	....	.3	....	....	....	.1	2.0	....
Acroperus harpae	....	.1	3.6	....	....	....	....	....
Synura uvella	....	.1	....	....	....	....	....	....
Phacus acuminata	....	.1	....	....	....	....	....	....
Polyarthra trigla*	....	11.3	....	....	.6	....	....	....
Keratella cochlearis*	....	4.0	....	....	....	....	....	....
Volvox globator	....	....	6.0	....	....	....	....	....
Centropyxis aculeata	....	....	7.2	....	....	....	....	1.1
Filinia longiseta	....	....	.1	....	....	....	.4	....
Simocephalus exspinosus	....	....	.4	....	....	....	....	....
Simocephalus vetulus	....	....	....	.2	....	....	.1	....
Keratella quadrata	....	....	....	....	.6	....	....	....
Scapholeberis mucronata	....	....	....	....	1.2	....	....	....

*Abundant in Lake Michigan.

TABLE 15.—AVERAGE SUMMER ABUNDANCE OF PLANKTON ORGANISMS IN FLOOD PLAIN LAKES, JUNE, JULY, AUGUST
(*Thousands per cubic meter*)

Species	Rock River Slough, So. of Erie, Ill. 1926	Hatwood Slough, Erie, Ill. 1926	Slough near Byron, Ill. 1926	Slough near Grand Detour, Ill. 1926	Slough near Colona, Ill. 1926	Horseshoe Lake, Ill. 1928	Wolf Lake, Union Co., Ill. 1928	Macon Lake, Inverness, Miss. 1927	Lake Dawson, Inverness, Miss. 1927
Trachelomonas volvocina	9.9	10.0	....	36.0	....	....	30.0	....	....
Difflugia lobostoma	424.5	.4	32.0	100.0	4.8	81.0	9.0	4.0	16.0
Codonella cratera	16.5	454.9	....	12.6	8.6	.5	.6	.2	9.6
Bosmina longirostris	76.0	....	32.0	17.7	....	.2	.3	....	.1
Keratella cochlearis	1.5	61.0	2.0	10.4	....	1.5	50.0	3.4	....
Brachionus calyciflorus	....	7.1	64.0	20.8	134.4	.3	.2	....	....
Polyarthra trigla	330.0	67.3	1.0	70.0	546.0	5.4	18.0	4.0	1.6
Synchaeta spp.	....	....	....	....	2.4	....	....	2.0	3.2
Cyclops viridis	9.9	4.0	128.0	127.7	9.0	2.5	1.2	....	....
Pediastrum duplex	8.1	100.2	3.0	5.0	15.6	.2	1.8	.4	16.0
Closterium acerosum	....	53.3	32.0	.4	.6	.3	.2	....	....
Synura uvella	....	....	....	....	....	1.6	.6	.4	....
Lysigonium granulatum	....	20,000.0	....	1,880.0	....	225.0	300.0	170.0	24.0
Chydorus sphaericus	.6	1.2	544.0	....	.1	.4	.5	....	....
Brachionus capsuliflorus	10.3	....	32.0	12.8	....	.2	.3	....	.1
Eudorina elegans	1.0	....	....	....	177.2	54.0	7.0	40.0	.1
Cyclops bicuspidatus	84.3	331.6	....	83.2	....	....	....	....	....
Diaptomus pallidus	89.1	2.3	....	....	....	5.4	....	....	....
Scenedesmus quadricauda	6.6	46.2	....	5.2	27.0	1.0	1.8	....	.4
Euglena viridis	6.6	36.0	96.0	7.8	29.0	1.0	6.0	....	1.6
Phacus longicauda	7.8	75.0	....	11.0	3.6	1.3	.1	4.0	.1
Asplanchna brightwellii	....	9.3	....	13.0	6.0	.2	.3	....	....
Filinia longiseta	....	....	....	....	120.0	13.5	.1	2.0	.1
Euglena oxyuris	7.8	4.6	....	2.6	72.0	4.0	42.0	....	....
Euglena acus	....	73.3	800.0	....	....	.2	12.0	6.0	.1
Diaphanosoma brachyurum	....	....	....	....	....	....	1.5	....	1.6
Ceratium hirundinella	....	1.0	32.0	....	35.0	16.2	2.0	2.0	1.6
Daphnia longispina	6.0	36.3	....	5.0	....	2.0	.1	....	....
Brachionus angularis	66.0	14.0	....	31.0	108.0	.3	1.2	14.0	.1
Pedalia mira	....	....	....	....	....	1.0	24.0	16.0	4.8
Brachionus budapestinensis	....	....	....	10.0	480.0	....	.1	....	.3
Moina micrura	....	....	....	....	....	....	.3	....	....
Moina brachiata	....	7.2	....	153.8	9.0	....	....	....	....
Brachionus havanaensis	3.1	....	....	1.3	222.0	....	....	2.0	....
Conochiloides natans	....	.2	....	13.0	....	.3	.9	6.0	....
Area in acres	1.2	5.0	1.0	2.0	12.0	1,800.0	500.0	1,000.0	2,000.0
Average depth in feet	8.0	4.0	2.0	3.0	3.0	5.0	6.0	6.0	10.0

TABLE 16.—RELATIVE ABUNDANCE OF PREDOMINANT ORGANISMS IN PLANKTON OF GLACIAL LAKES
(*abd.* = *abundant; com.* = *common; occ.* = *occasional*)

Species	Lake Superior, Minnesota, (6 collections) July, Aug., 1928	Lake Winnebago, Wisconsin, (3 collections) June, 1892	Long Lake, Illinois, (10 collections) Summer, 1916	Lake Chautauqua, N. Y., (2 collections) Aug., 1928	Douglas Lake, Michigan, (2 collections) Aug., 1914	Sand Lake, Illinois, (12 collections) Summer, 1916	Oconomowoc Lake, Wisconsin, (4 collections) Aug., 1927	Long Lake, Minnesota, (3 collections) Aug., 1927	White Iron Lake, Minnesota, (3 collections) Aug., 1927	Lake Michigan, Illinois, (10 collections) 1926-27
Lysigonium granulatum	abd.	com.	abd.	com.	com.	....	....	abd.	com.	com.
Fragilaria crotonensis	abd.	occ.	abd.	occ.	occ.	abd.	abd.	com.	com.	abd.
Asterionella gracillima	abd.	occ.	....	....	....	com.	....	com.	abd.	abd.
Striatella fenestrata	abd.	....	....	com.	abd.	....	....	com.	com.	abd.
Scenedesmus quadricauda	....	....	....	....	....	....	rare	occ.	....	rare
Pediastrum duplex	occ.	rare	com.	occ.	....	rare	rare	....	....	rare
Aphanocapsa sp.	com.	....	....	....	....	....	occ.	com.	abd.	occ.
Difflugia globulosa	occ.	....	com.	occ.	com.	occ.	occ.	occ.	occ.	occ.
Ceratium hirundinella	occ.	occ.	abd.	com.	occ.	abd.	abd.	abd.	com.	com.
Codonella cratera	occ.	....	rare	....	....	....	....	rare	....	occ.
Eudorina elegans	com.	....	occ.	....	....	....	....	....	....	rare
Synura uvella	rare	....	rare	....	com.	....	....	com.	....	....
Keratella cochlearis	com.	rare	com.	com.	occ.	abd.	com.	rare	rare	occ.
Keratella quadrata	rare	....	....	....	....	....	....	....	....	occ.
Polyarthra trigla	occ.	....	com.	occ.	rare	abd.	com.	rare	occ.	occ.
Notholca longispina	com.	occ.	....	....	com.	abd.	rare	occ.	occ.	occ.
Asplanchna brightwellii	rare	....	....	....	....	....	abd.	....	....	....
Notholca striata	rare	....	....	....	....	....	....	....	....	....
Diaphanosoma brachyurum	rare	occ.	com.	occ.	occ.	com.	....	....	abd.	....
Daphnia longispina	com.	....	com.	....	....	abd.	....	....	....	....
Daphnia retrocurva	occ.	com.	abd.	com.	occ.	com.	....	com.	occ.	occ.
Bosmina longirostris	occ.	....	....	....	....	abd.	....	....	....	....
Bosmina longispina	occ.	abd.	....	occ.	occ.	com.	abd.	occ.	rare	com.
Chydorus sphaericus	rare	com.	com.	com.	com.	com.	occ.	occ.	occ.	occ.
Leptodora kindtii	....	....	occ.	....	....	occ.	....	com.	com.	rare
Limnocalanus macrurus	occ.	....	....	....	....	....	....	....	....	occ.
Epischura lacustris	occ.	....	....	....	....	....	....	....	....	occ.
Diaptomus ashlandi	rare	....	....	....	....	....	....	....	....	rare
Diaptomus oregonensis	....	abd.	abd.	com.	com.	abd.	occ.	com.	com.	..
Diaptomus minutus	com.	....	....	....	....	....	....	occ.	occ.	com.
Cyclops viridis	occ.	occ.	com.	rare	rare	occ.	occ.	rare	rare	occ.
Cyclops bicuspidatus	com.	com.	abd.	....	occ.	abd.	....	....	occ.	occ.
Cyclops leuckarti	rare	rare	occ.	com.	....	abd.	com.	....	com.	....
Anabaena circinalis	....	....	abd.	abd.	....	....	com.	abd.	....	occ.
Anabaena spiroides	....	....	abd.	....	....	....	....	occ.	abd.	....
Microcystis aeruginosa	....	....	abd.	....	....	abd.	....	occ.	occ.	....
Coelosphaerium naegelianum	....	....	abd.	....	....	com.	com.	com.	abd.	rare

TABLE 17.—MONTHLY AVERAGES OF VELOCITY AND AGE OF WATER IN THE SANGAMON RIVER, 1928, CORRELATED WITH THE ABUNDANCE OF PLANKTON
(*abd. = abundant; com. = common; occ. = occasional*)

Month	Velocity in Feet per Hour	Gage Readings at Monticello in Feet	Age of Water and Relative Abundance of Plankton			
			Mahomet	Monticello	Rhea's Bridge	Lost Bridge
February	9,000	8.72	19.9 hr.	1 da., 13.2 hr.	5 da., 13.2 hr. Plankton scarce	10 da., 1.0 hr. Plankton scarce
March	2,500	6.08	3 da.	5 da., 3.1 hr.	19 da., 23.5 hr. Plankton occ.	35 da., 17.8 hr. Plankton com.
April	2,200	6.94	3 da., 9.6 hr.	5 da., 16.8 hr. Plankton scarce	22 da., 16.9 hr. Plankton occ.	40 da., 21.6 hr. Plankton com.
May	1,260	4.60	5 da., 10.5 hr.	11 da., 6.6 hr. Plankton occ.	39 da., 15.4 hr. Plankton com.	71 da., 17.8 hr. Plankton abd.
June	2,340	4.72	3 da., 5.1 hr.	5 da., 8.2 hr. Plankton occ.	21 da., 8.3 hr. Plankton com.	38 da., 15.1 hr. Plankton abd.
July	1,800	4.92	4 da., 2.7 hr.	7 da., 21.4 hr. Plankton scarce	27 da., 18 hr. Plankton abd.	50 da., 5.2 hr. Plankton abd.
August	1,080	2.46	6 da., 22.3 hr.	13 da., 3.6 hr. Plankton occ.	46 da., 6 hr. Plankton abd.	83 da., 16.8 hr. Plankton abd.
September	1,500	2.49	5 da.	9 da., 11.3 hr. Plankton occ.	33 da., 9.2 hr. Plankton abd.	62 da., 8.3 hr. Plankton abd.
October	720	3.58	10 da., 9.4 hr.	19 da., 17.5 hr. Plankton com.	69 da., 9 hr. Plankton com.	125 da., 13.5 hr. Plankton abd.
November	1,720	4.48	4 da., 8.4 hr.	8 da., 6.2 hr. Plankton scarce	29 da., 1 hr. Plankton occ.	52 da., 13.3 hr. Plankton abd.
December	3,600	6.00	2 da., 1.8 hr.	3 da., 22.7 hr. Plankton very scarce	13 da., 21 hr. Plankton very scarce	25 da., 2.7 hr. Plankton com.
Equivalent mileage from source			34	57	228	409

TABLE 18.—AVERAGE ABUNDANCE OF PREDOMINANT ORGANISMS IN PLANKTON OF THE SANGAMON RIVER, INCLUDING LAKE DECATUR, JULY, 1928, SHOWING CORRELATION WITH AGE OF WATER
(*Thousands per cubic meter*)

Species	Mahomet	Monticello	Rhea's Bridge	Lost Bridge
Diatoms (mostly bottom forms)	48,000.0	20,000.0	37.0	.3
Cyclops viridis	.5	.5	6.0	3.6
Difflugia lobostoma	......	33.3	70.0	15.0
Euglena viridis*	......	24.0	180.0	344.4
Trachelomonas volvocina*	......	24.0	3,600.0	3,305.2
Closterium acerosum	......	.3	.5	.3
Brachionus angularis	......	+	.1	3.2
Bosmina longirostris	......	.4	2.0	.1
Cyclops bicuspidatus	......	.2	.2	31.6
Scenedesmus quadricauda	......	20.0	32.0	1,107.0
Brachionus capsuliflorus	......	+	1.0	No June record
Diaphanosoma brachyurum	......	......	36.0	12.8
Polyarthra trigla	......	......	+	7.5
Keratella cochlearis	......	......	+	22.6
Moina micrura	......	......	4.0	5.0
Brachionus calyciflorus	......	......	1.0	10.0
Chydorus sphaericus	......	......	.2	1.2
Asplanchna brightwellii	......	......	.6	1.0
Lysigonium granulatum*	......	......	......	200,000.0
Codonella cratera*	......	......	......	1,000.0
Pediastrum duplex	......	......	......	2.5
Synchaeta pectinata	......	......	......	10.8
Tintinnidium fluviatilis	......	......	......	42.7
Ceratium hirundinella	......	......	......	.8
Filinia longiseta	......	......	......	1.5
Diaptomus siciloides	......	......	......	2.6
Phacus longicauda	......	......	......	.3
Pedalia mira	......	......	......	.5
Brachionus havanaensis	......	......	......	.5
Leptodora kindtii	......	......	......	.1
Euglena oxyuris	......	......	......	.3
Age of water in days	3	6	20	40

*Decanted collections. + = less than 100 per cubic meter.

TABLE 19.—DEVELOPMENT OF PLANKTON IN LAKE DECATUR, 1923-1928
Averages for June, July, and August Collections
(Thousands per cubic meter)

Species	1923	1926	1927	1928
Pedalia mira	1.0	1.5	.2	4.3
Euglena oxyuris	1.3	.5	45.8	2.4
Lysigonium granulatum	68.3	891.2	10,667.4	90,214.0
Codonella cratera	63.3	33.4	365.7	1,158.7
Difflugia lobostoma	+	25.7	93.1	70.4
Polyarthra trigla	8.0	19.1	53.3	16.0
Keratella cochlearis	4.1	6.5	6.2	11.9
Pediastrum duplex	14.7	42.1	2.7	2.8
Euglena viridis	13.9	3.8	49.4	1,982.1
Cyclops viridis	533.7	3.9	.3	11.8
Eudorina elegans	11,033.8	6.6	8.6	4.5
Scenedesmus quadricauda	1.6	2.1	43.5	383.6
Phacus longicauda	1.0	.4	.8	10.7
Synchaeta pectinata	541.7	21.2	....	3.6
Brachionus calyciflorus	13.6	1.6	....	3.8
Brachionus angularis	14.4	....	3.0	2.8
Filinia longiseta	4.6	....	5.7	6.5
Asplanchna brightwellii	1.0	....	4.1	.5
Brachionus capsuliflorus	38.2	....	9.8	....
Daphnia longispina	1.7	....	2.6	....
Pleodorina illinoisensis	52.0	....	....	....
Closterium acerosum	....	.1	+	.1
Ceratium hirundinella	....	180.1	2.7	292.1
Diaphanosoma brachyurum	....	.9	1.1	5.5
Bosmina longirostris	....	5.0	9.7	.1
Tintinnidium fluviatilis	....	.8	53.2	1,107.4
Trachelomonas volvocina	....	1.3	8,702.8	18,786.4
Cyclops bicuspidatus	....	133.7	....	16.3
Diaptomus siciloides	....	4.4	....	15.5
Leptodora kindtii	....	.1	....	+
Aphanocapsa sp	....	.8	....	15.8
Microcystis aeruginosa	....	10.2	....	....
Synchaeta stylata	....	....	9.3	3.7
Brachionus havanaensis	....	....	.2	.1
Euglena acus	....	....	1.7	....
Brachionus budapestinensis	....	....	8.3	....
Conochiloides natans	....	....	....	.1
Anabaena circinalis	....	....	....	400.0

+ = less than 100 per cubic meter.

TABLE 20.—ABUNDANCE OF PLANKTON PREDOMINANTS IN SERIES OF LAKES IN WAUKESHAW COUNTY, WISCONSIN, SEPTEMBER, 1927
(Thousands per cubic meter)

Species	Oconomowoc Lake	Pewaukee Lake	Lulu Lake
Peridinium spp.	700.0	......	......
Glenodinium sp.	85.5	......	......
Difflugia globulosa	3.5	......	......
Asplanchna sieboldii	7.0	......	......
Cyclops leuckarti*	14.0	......	......
Notholca longispina*	1.0	......	......
Daphnia retrocurva*	.3	......	......
Bosmina longispina*	1.4	......	......
Chydorus sphaericus	.3	1.0	......
Coelosphaerium naegelianum	52.5	2,000.0	......
Ceratium hirundinella	350.0	500.0	528.0
Polyarthra trigla	14.0	35.0	2.0
Keratella cochlearis	24.5	400.0	594.0
Diaptomus oregonensis	.7	1.0	2.6
Synedra acus	140.0	15.0	825.0
Fragilaria crotonensis	1,400.0	300.0	2,640.0
Scenedesmus quadricauda	.3	1.0	99.0
Pediastrum duplex	.7	40.0	198.0
Chroococcus sp.	7.0	750.0	137.5
Aphanocapsa sp.	140.0	1,500.0	26.4
Anabaena circinalis	......	......	......
Microcystis aeruginosa	......	100.0	......
Ceriodaphnia lacustris	......	2.5	......
Codonella cratera	......	.5	......
Euglena viridis	......	.5	4.0
Dinobryon sertularia	......	25.0	1,320.0
Bosmina longirostris	......	3.0	66.0
Asterionella gracillima	......	96.0	3,300.0
Lysigonium granulatum	......	4,000.0	13,200.0
Cyclops viridis	......	3.0	.6
Pompholyx complanta	......	......	52.8
Synchaeta pectinata	......	......	66.0
Diaphonosoma brachyurum	......	......	.6
Mean depth in meters	9.5	3.9	2.0

*Deep lake predominants.

TABLE 21.—ABUNDANCE OF PLANKTON PREDOMINANTS IN REPRESENTATIVE BODIES OF WATER, BASED ON SUMMER AVERAGES (JUNE, JULY, AND AUGUST), SHOWING THE RELATION OF THE DIFFERENT COMMUNITIES

(Thousands per cubic meter)

Species	Stable Stream	Impounded Stream	Young Stream	Perennial Pond	Temporary Pond	Glacial Lake
Microcystis aeruginosa	23,333.0	2.5	......	95.6	......	549,812.0
Trachelomonas volvocina	23,256.0	6,872.6	50.8	11,280.1	5,000.0	......
Polyarthra trigla	74.6	24.1	.+	164.3	3.0	22.4
Brachionus calyciflorus[1]	166.5	4.7	.4	47.4	......	......
Difflugia globulosa[2]	23.5	......	......	......	......	7.1
Keratella cochlearis	17.5	7.2	.3	284.6	.+	87.4
Difflugia lobostoma	19.9	47.5	12.7	340.4	42.0	......
Codonella cratera	1,967.0	405.3	1.1	440.6	......	.5
Chydorus sphaericus	.3	......	.+	.+	5.0	2.7
Lysigonium granulatum	4,303.0	25,480.2	......	262.0	......	1,242.6
Cyclops bicuspidatus	......	37.7	.8	22.2	40.0	2.0
Scenedesmus quadricauda	9.6	107.7	.+	11,574.1	6.0	.+
Brachionus capsuliflorus[1]	2.8	12.0	.+	1.3	......	......
Phacus longicauda	5.7	3.2	......	503.6	.2	......
Asterionella gracillima	2.6	......	......	......	......	139.9
Eudorina elegans	24.4	2,763.5	......	......	20.0	1.6
Bosmina longirostris	4.9	3.7	1.0	124.8	......	4.9
Cyclops viridis	2.0	137.4	.1	197.5	2.0	......
Pediastrum duplex	65.8	13.6	.5	244.8	......	2.7
Brachionus angularis[1]	62.8	5.1	.5	82.3	......	......
Filinia longiseta[1]	5.8	4.2	......	10.7	......	......
Conochiloides natans[1]	17.2	.+	......	48.4	......	......
Euglena acus	196.9	.4	......	......	......	......
Euglena viridis	2,145.4	512.3	23.4	2,226.1	10,000.0	......
Euglena oxyuris	1,821.0	12.5	......	......	......	......
Diaphanosoma brachyurum	2.6	1.8	......	5.4	......	.9
Tintinnidium fluviatilis[1]	1,551.0	290.3	......	71.8	......	......
Pedalia mira[1]	18.1	1.7	......	......	......	......
Closterium acerosum	.6	.+	.1	.4	2.0	......
Asplanchna brightwellii	4.3	1.4	......	2.7	......	1.7
Brachionus budapestinensis	26.4	2.0	......	......	......	......

TABLE 21—(*Concluded*)

Species	Stable Stream	Impounded Stream	Young Stream	Perennial Pond	Temporary Pond	Glacial Lake
Moina micrura[1]	.7	......	......	......	......	......
Leptodora kindtii	.+	.+	......	......	......	.+
Brachionus havanaensis	.3	.1	.1	73.2	.8	......
Ceratium hirundinella	1.4	118.7	.+	107.8	......	470.7
Diaptomus pallidus	.2	......	......	47.3	......	......
Daphnia longispina	.7	1.0	1.4	80.9	.5	253.0
Diaptomus siciloides	.1	5.0	......	......	......	......
Synchaeta pectinata	33.6	141.6	......	......	......	......
Synchaeta stylata	5.5	3.2	......	......	......	......
Aphanocapsa sp.	150.0	4.1	......	62.0	......	758.7
Anabaena circinalis	1,500.0	100.0	......	......	......	18,132.5
Arcella vulgaris	......	......	2.4	......	6.0	......
Cyclops serrulatus[3]	......	......	.+	......	3.0	......
Camptocercus rectirostris[3]	......	......	......	......	1.0	......
Simocephalus vetulus[3]	......	......	......	......	5.0	......
Trachelomonas hispida	......	......	......	......	5,000.0	......
Lepadella acuminata	......	......	......	......	.7	......
Daphnia pulex	......	......	......	......	2.5	......
Platyias quadricornis	......	......	......	......	1.7	......
Scapholeberis mucronata	......	......	......	......	11.0	......
Pleuroxus denticulatus	......	......	......	......	.6	......
Brachionus patulus	......	......	......	......	10.0	......
Fragilaria crotonensis[2]	......	......	......	......	......	29.3
Notholca longispina[2]	......	......	......	......	......	1.3
Daphnia retrocurva[2]	......	......	......	......	......	1.9
Bosmina longispina[2]	......	......	......	......	......	1.9
Cyclops leuckarti[2]	......	......	......	......	......	5.8
Diaptomus oregonensis[2]	......	......	......	......	......	4.9
Diaptomus minutus[2]	......	......	......	......	......	.9
Epischura lacustris[2]	......	......	......	......	......	12.0

[1]Stable river predominants. [2]Glacial Lake predominants. [3]Temporary pond predominants. + = less than 100 per cubic meter.

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UNIVERSITY OF ILLINOIS BULLETIN

Vol. XXXI   ISSUED WEEKLY—JULY 1, 1934   No. 45

A Study of Fresh-water Plankton Communities

BY

SAMUEL EDDY

PRICE $1.00

ILLINOIS BIOLOGICAL MONOGRAPHS

Vol. XII   No. 4

PUBLISHED BY THE UNIVERSITY OF ILLINOIS
URBANA

Entered as second-class matter, Dec. 11, 1912, at the post office at Urbana, Illinois, under the Act of August 24, 1912. Acceptance for mailing at the special rate of postage provided for in section 1103, Act of October 3, 1917, authorized July 31, 1918.

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